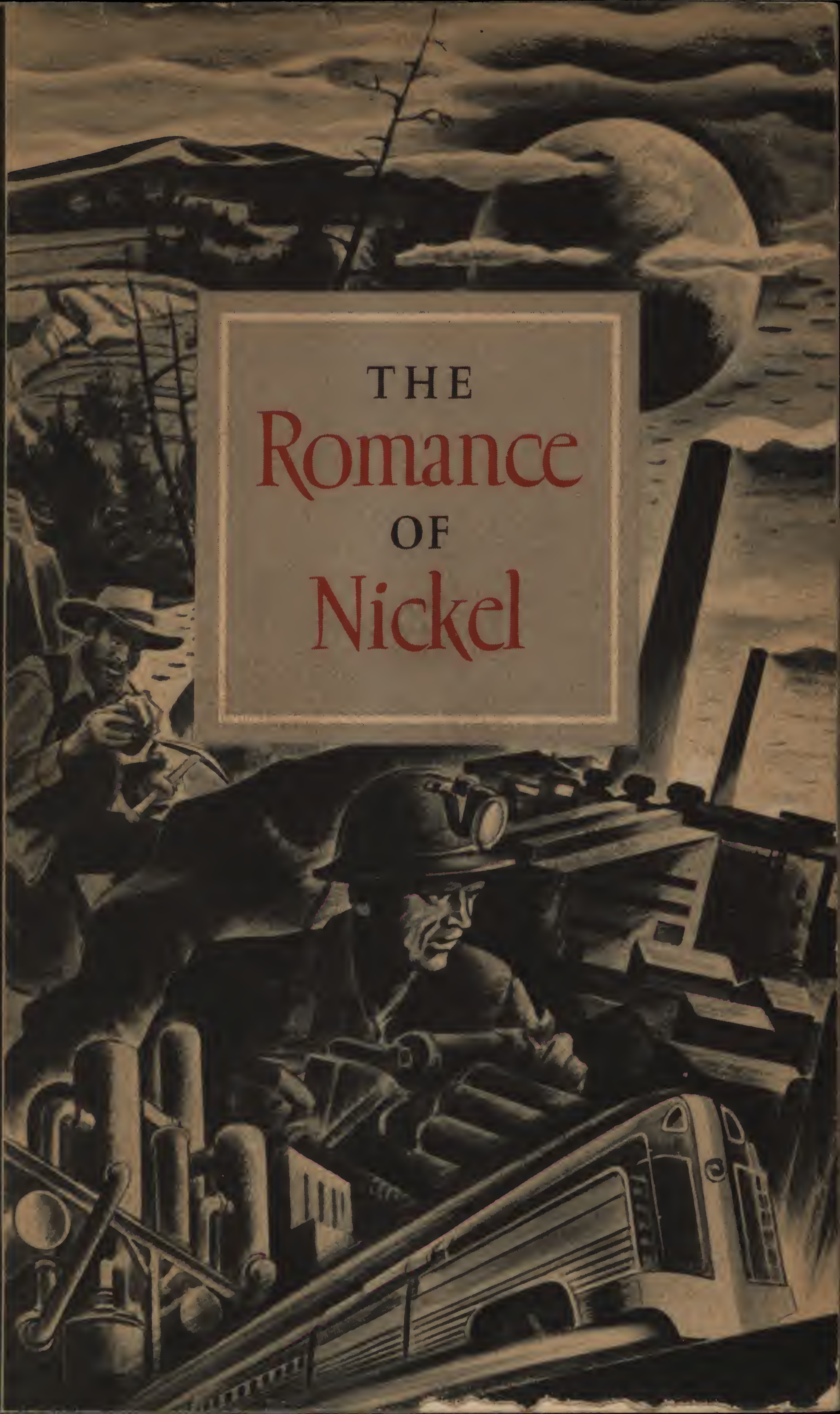
THE Romance OF Nickel



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THE ROMANCE OF NICKEL

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FOREWORD

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Scientists estimate that there is about twice as much nickel in the earth's crust as there is copper, zinc and lead combined. In the past, nickel has been mined in a great many countries, and in recent years has been mined in quantity in Canada, Celebes, Cuba, New Caledonia, Norway and Russia, and in smaller amounts in several other countries. Occurrences in South and Central America, Africa and the Philippine Islands have also been explored in the search for other commercial deposits.

The important position of Canada in nickel production has been maintained by the constant effort to uncover and develop its ore bodies, to create better methods of getting that ore out of the earth and to provide economies in its smelting and refining.

The success of research in developing new and improved nickel alloys has resulted in the extensive use of nickel in the United States, in the production of materials for improved equipment requiring qualities of strength, toughness and resistance to corrosion, wear and heat, as well as other special and useful properties.

The Romance of Nickel was printed originally in Canada in answer to the many requests in that country for the story of one of its major enterprises. In view of the many applications of nickel in the United States, it was felt that an edition in this country of the Romance of Nickel would also be of interest.

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PART ONE:

NICKEL DOWN THROUGH THE AGES

In the Beginning

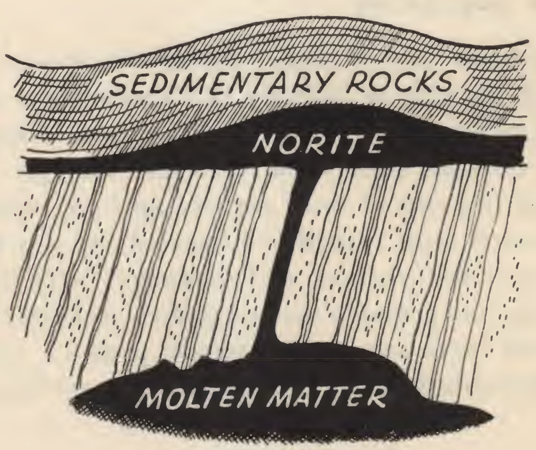
In that bleak belt of rocky country which lies to the north of the city of Sudbury in Canada, some of the world's richest mineral deposits have been discovered during the past sixty years. How did they get there? It was during one of those periods, ages ago, when the earth's outer crust twisted and buckled and was shaken by volcanic disturbances, and mountains were formed.

During that period, a mass of molten rock deep down inside the earth came under terrific pressure, and was forced towards the earth's surface where there happened

to be a line of weakness in the earth's crust. As this molten rock was pushed upwards, it came in contact with the under side of thick layers of sedimentary rocks and spread out, forming a large, oval-shaped mass that gradually began to cool and harden into solid crystalline rock known as norite.

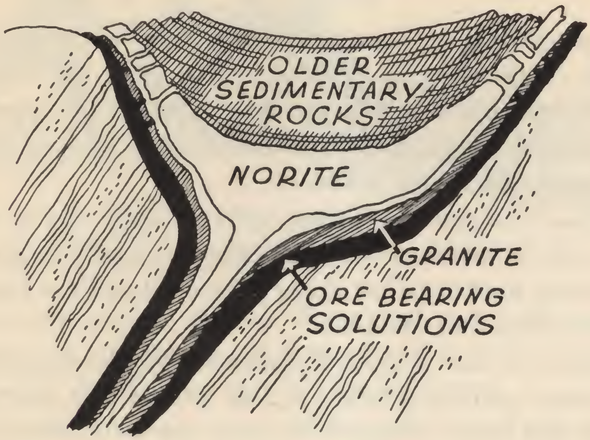
The pressure inside the earth continued. The earth's crust twisted and folded again. A second mass of molten rock, this time of a granite type, was pushed towards the earth's surface. It forced its way into the cracks and crushed areas of the rocks, particularly along the margins of the norite. There it formed irregular masses and dikes and began to cool and harden into granite. Some time during this period the norite mass was caught in the gigantic vise of a major fold in the earth's crust and was folded and bellied downward, and the overlying sediments were forced downward into the centre of the bowl.

While great earth forces continued to twist and bend the rocks, a third mass of hot material was forced towards the earth's surface. Apparently it was composed



Molten matter, forced up through the earth's crust, came in contact with the under side of layers of overlying sedimentary rocks and spread out.

Cross section of Sudbury Basin as geologists believe it exists today.



of hot chemical solutions and gases under enormous pressures. These were forced into the cracks and crushed areas along the margins of the norite and the granite masses, and into clefts in the nearby rocks.

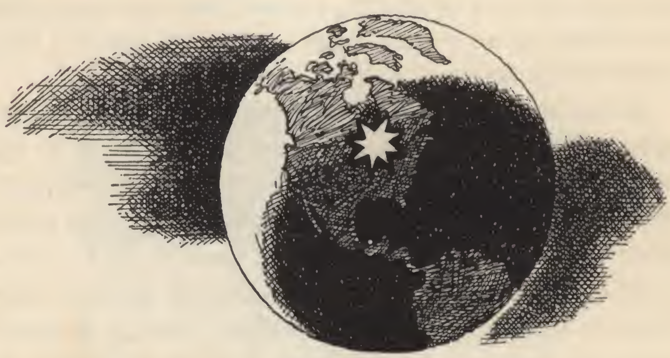
These solutions carried the copper and nickel and other important elements which were deposited in the crevices and in the nearby rocks. Thus the ore bodies containing these metals came into being under a deep cover of volcanic and sedimentary rocks.

As the ages passed and the great disturbances of that particular period subsided, nature went to work to tear down that which she had so laboriously and fantastically fashioned. Great volumes of rock material were gradually worn away by the rain, wind and ice, and as these rocks disappeared the norite, granite and the ore bodies came to light. The great oval-shaped outcrop of norite, with the sediments within and the ore bodies at the outer margins and along the zones where the rocks had previously been cracked and crushed, has been named the Sudbury Basin.

The surface, as man sees it today, is just that part which happens to be exposed at this time by the erosional processes. Study of this surface makes one wonder what might have existed above and been carried away, and what now exists below.

Thus have geologists after years of study of this surface and the mines in this locality constructed the theory regarding the formation of the great ore bodies of nickel, copper and other metals.

Can it be that Divine Providence, in the beginning of things, pointed a finger at this spot on the spinning globe and said, "Here must rich stores of nickel be hidden away, so that, as the great plan is unfolded down through the ages, this metal may be brought to light to play a deciding part in the affairs of men that are to be"?



Early History of Nickel

Although used in natural alloys even in ancient times, nickel was unkown as an element until 1751, when its discovery came about in the following way:

Miners in Saxony, several years before, had attempted to smelt some newly-discovered ores which had the appearance of copper ore. But the metal they obtained was not copper — it was a white metal so hard and tough it could not be hammered into useful articles, and so was useless to them. Believing Old Nick had cast a spell over their ores, the superstitious miners called the metal "Kupfer-Nickel," meaning "Old Nick's Copper."

In the years that followed, similar ores were encountered in various places, and among mining men "Kupfer-Nickel" was the name invariably used for the hard, white metal these ores produced.

A Swedish scientist named Cronstedt spent five years experimenting with ores of this kind and came to the conclusion that kupfer-nickel contained a metal previously unknown to men. He called his new metal "Nickel."

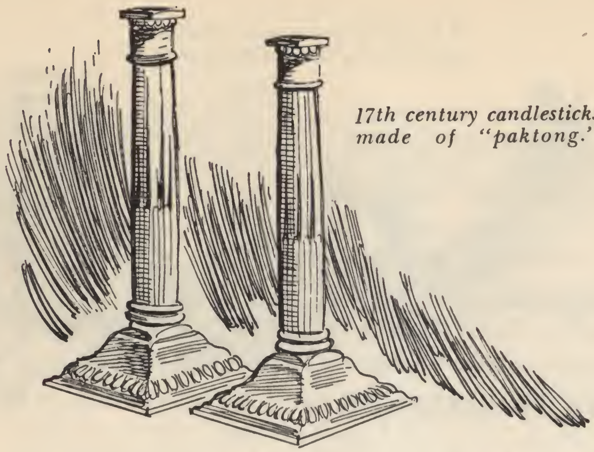
Early miners could not smelt nickel-bearing ores. They called the hard, tough metal "Old Nick's Copper."

But the influence of this unknown metal had been felt even back in the dawn of history. It is believed that ancient oriental peoples learned at an early date to make useful implements out of meteorites. The tradition that the swords of the great warriors of old in China, Persia and Northern Europe were "Heaven-sent" seems to indicate that they were made from meteorites which fell from the heavens. The unusual keenness of their blades was probably due to the toughening effect of nickel in the iron — nickel and iron frequently occur together in metallic meteorites.

Beautiful boxes and candlesticks made of a white metal called "paktong" made in China since ancient days by adding zinc to what we now know to have been nickel-copper ores, were brought to Europe by the East India Company in the seventeenth century.

Five years after Cronstedt discovered nickel, another Swedish scientist, Von Engestrom found that "paktong"

Nickel-copper ores mined in southern China were sent by caravan to Canton where zinc was added. The resulting metal, called "paktong" or white copper, was used for making candlesticks and boxes which were brought to England by the East India Company in the 17th and 18th centuries.



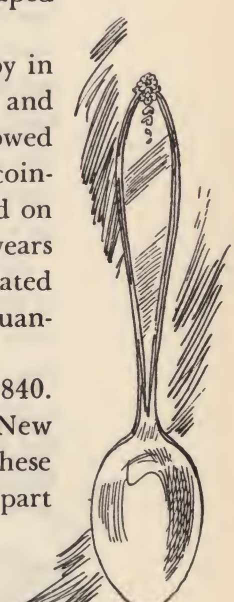
17th century candlesticks made of "paktong."

contained copper, nickel and zinc. Soon similar alloys were being produced in Europe and were known as German silver and later as nickel silver.

When electro-plating was introduced in England in 1844, articles made of German silver and plated with silver became popular in place of the more expensive Sheffield plate. Silver plated articles today are still shaped from nickel-silver, then electro-plated with silver.

Belgium introduced coins of a nickel-copper alloy in 1860. Switzerland issued pure nickel coins in 1881, and in the years to come one country after another followed suit. In 1939, over one hundred governments had coinage containing nickel. Nickel plating was developed on a commercial basis about 1870. And for many years nickel plating, coinage and nickel silver for silver-plated ware remained the three chief uses for the small quantities of nickel being produced in the world.

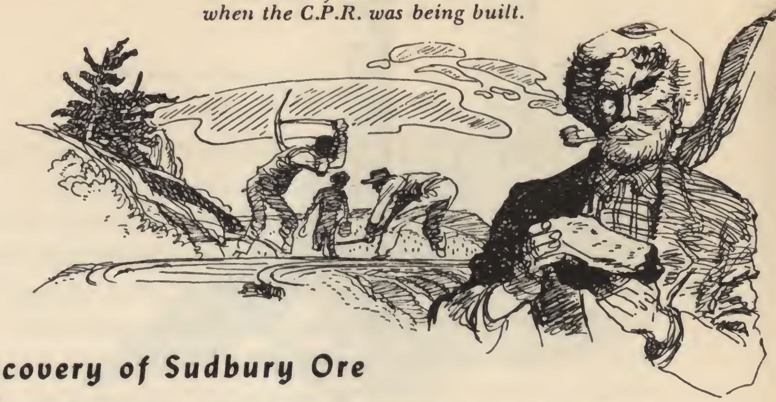
Nickel deposits were developed in Norway after 1840. Then nickel mines were opened up in the island of New Caledonia in the South Seas about 1877, and these remained the chief source of supply till the latter part of the nineteenth century.



Silver-plated ware is stamped from nickel silver (about 18% nickel alloyed with copper and zinc), then silver plated.

The first pure nickel coin ever issued was a 20-centime piece issued in Switzerland in 1881.

The Sudbury ore was discovered when the C.P.R. was being built.

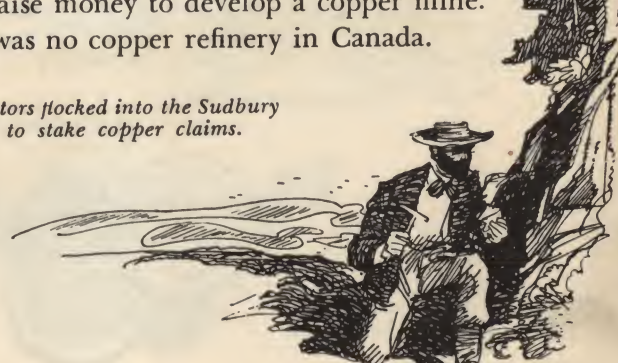


Discovery of Sudbury Ore

Meanwhile the hand of destiny was drawing closer to the great store of nickel locked in the rocks on the other side of the world. Columbus discovered America in 1492. French coureurs de bois pushed their way up the Great Lakes. Colonists settled in Eastern Canada, in British Columbia and a few scattered districts on the Prairies. There was talk of Confederation. So that Canada might stretch from sea to sea, Sir John A. Macdonald's government promised to build a transcontinental railway to bring British Columbia into Confederation. As this railway was being blasted through the rocky wilderness north of Georgian Bay, workmen uncovered a corner of a great ore body deposited there ages before.

Soon prospectors flocked into the Sudbury district to stake what looked like rich copper claims, for at that time no one dreamed that this deposit contained nickel. But to develop a mine in Canada's pre-Cambrian rocks requires years of effort and large sums of money. It was not easy to raise money to develop a copper mine. Moreover there was no copper refinery in Canada.

Prospectors flocked into the Sudbury district to stake copper claims.



Beginning of the Canadian Nickel Industry

That was the way matters stood when Samuel J. Ritchie came on the scene. Ritchie, a man of great driving force and persuasive power, had been trying to develop iron ore deposits in Hastings County, Ontario, and had built a railroad from there to the port of Trenton on Lake Ontario. Eventually he found that these iron ores could not be developed profitably, and the railroad's chief source of revenue disappeared.

The newly discovered Sudbury ores seemed to Ritchie to be a good way to provide a new source of revenue for his railroad. With ore reported to run more than seven per cent copper, he would extend the line to Sudbury, or hook it up with the C.P.R. Yes, this little mining camp away back in the wilderness would one day be a great thriving industrial centre.

So it wasn't long before Ritchie had purchased the most promising claims in the Sudbury district, and organized the Canadian Copper Company to develop them.

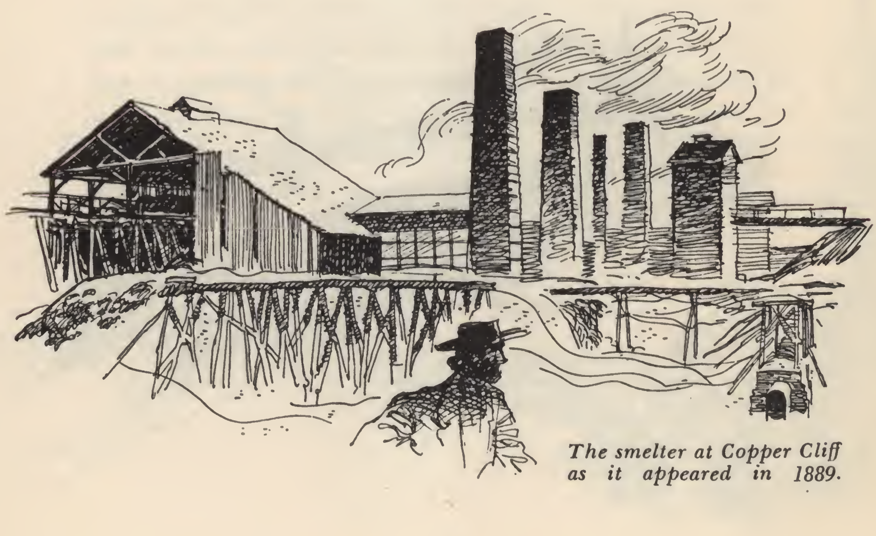
The Central Ontario Railway was built to haul iron ore from Hastings County to Trenton, on Lake Ontario.

R. M. Thompson, when still a young man, had become manager of the Orford Copper and Nickel Company, a company organized in Quebec to operate mines near the village of Orford in that province. Finding it difficult to sell the matte (or partially refined metal), at a profit in Swansea, Wales, where the nearest suitable smelting facilities were then available, the company built its own smelter at Bayonne, New Jersey, where there was a promising market for copper in the heart of the growing industrial region of the United States.

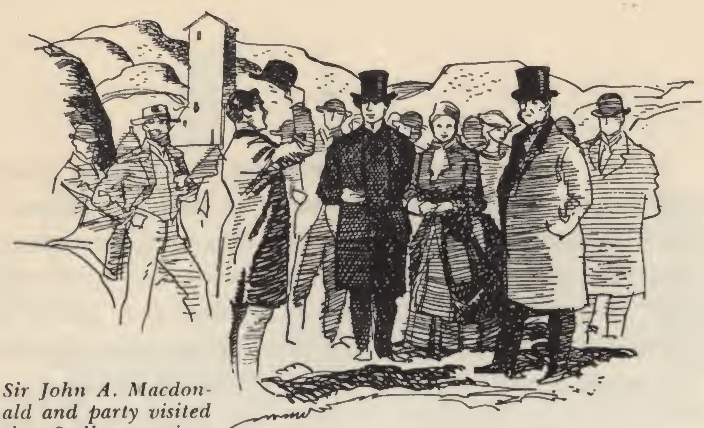
Soon copper ores began coming in for refining from new mines in the east and in the west. Ritchie, too, up in Sudbury, looked around for a refinery to handle his ore. He made an agreement with Thompson to ship one hundred thousand tons of copper ore to the Orford smelter.

Mining Begins at Sudbury

So in 1886 mining operations were begun near Sudbury. At that time no one had the slightest conception of the important part these mines were to play in the life of Canada and in its export trade throughout the world.



The smelter at Copper Cliff as it appeared in 1889.



Sir John A. Macdonald and party visited the Sudbury mines in 1886.

But even at that early period, Sir John A. Macdonald, premier of Canada, accompanied by Lady Macdonald, Sir Charles Tupper, and Canada's two great railroad pioneers, George Stephens (later Lord Mountstephen) and Sir William Van Horne, paid a visit to the little mining settlement. These were men who foresaw that Canada's future greatness lay in the development of her railroads, her mineral wealth, her timber and her agriculture. They were ready to encourage anyone who would invest money in the development of Canada's natural resources.

Nickel Makes Trouble Again

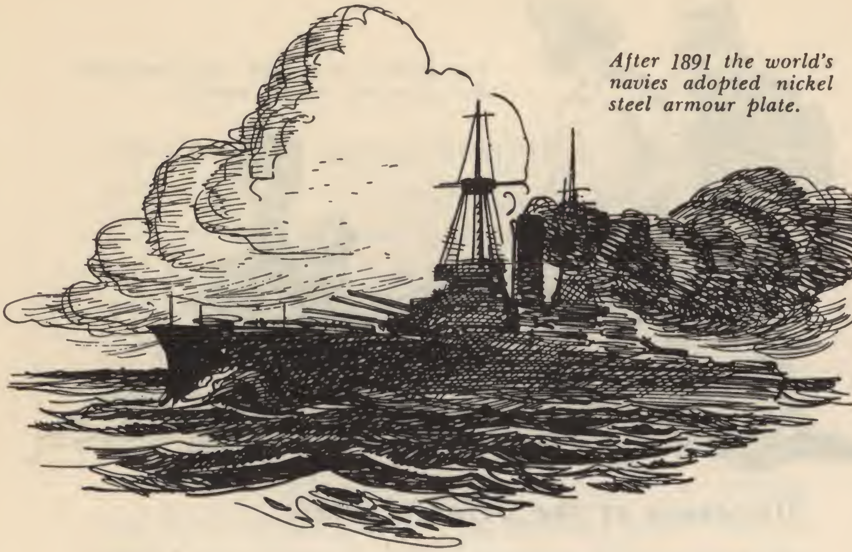
When the first batch of metal from the Sudbury ore poured from the furnace down in the New Jersey refinery, Thompson knew he was in for trouble. You couldn't sell that kind of metal to copper customers. He had an analysis made. It contained nickel . . . and nickel was still the trouble maker among metals as it had been to the miners of Saxony more than a century before. Ritchie with his mines at Sudbury seemed likely to be ruined.

In the face of this disheartening news, most men would have thrown up their hands in despair. Thompson set himself resolutely to the task of solving the nickel-copper separation problem. Ritchie refused to be downcast. Nickel, he discovered, was selling at a dollar a pound, almost ten times the current price of copper. But world production was only a thousand tons a year. His mines could produce twice that much. He must find new uses for nickel besides plating, coinage and nickel silver.

Nickel Steel Proves Itself

So Ritchie set himself to the task of finding new uses for those large quantities of nickel he knew his mines could produce. He even wrote to Krupp the German gun maker to try to interest him in nickel steel. Krupp replied that the small quantities of nickel available in the world did not warrant experimental work in this direction.

Sir Charles Tupper accompanied Samuel Ritchie to Europe in 1890 in search of new markets for nickel.

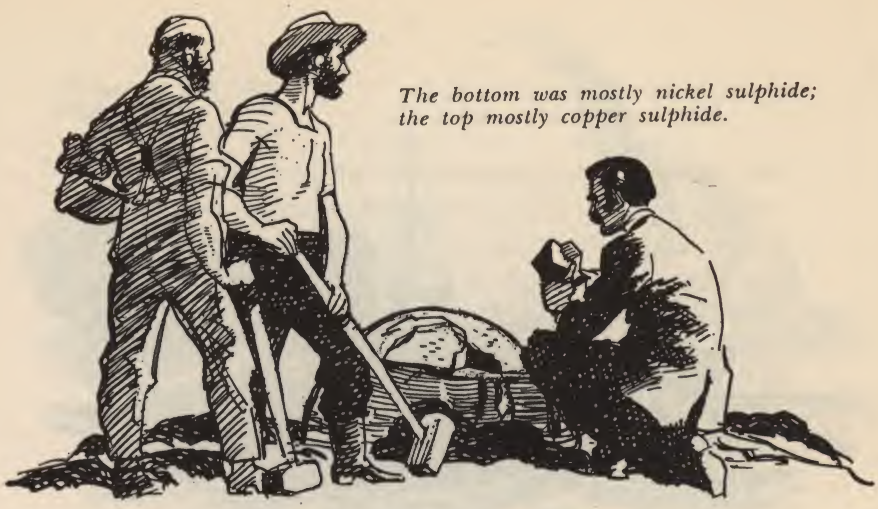


After 1891 the world's navies adopted nickel steel armour plate.

But experimental work had been going on in France and England. The Canadian government had faith in the future of the nickel mines, and Sir Charles Tupper accompanied Ritchie to Europe to try to interest European industrialists in Canadian Nickel.

In 1889 James Riley in Glasgow issued a report of experiments he had conducted with nickel steel. Ritchie brought this report to the attention of the United States navy and a series of tests was arranged. When eight-inch armour-piercing shells were fired at short range at two pieces of armour plate, the nickel steel plate proved definitely superior to the plain steel plate.

Now the great navies of the world began to take a keen interest in nickel steel. The United States navy asked Thompson to supply a large tonnage of nickel which he at that time had no way of producing. Inside of a few months he did succeed in making a red oxide of iron and nickel. While this was acceptable to the navy, the refining costs were equal to or greater than the price he was being paid.



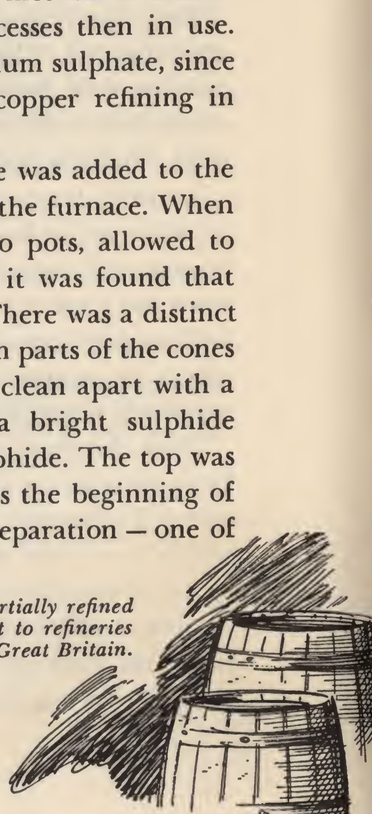
The bottom was mostly nickel sulphide; the top mostly copper sulphide.

Discovery of the Orford Process

So Thompson began experimental work to try to discover a better and more economical method of nickel-copper separation than the wet processes then in use. Finally someone suggested trying sodium sulphate, since he had seen this material used in copper refining in Scotland.

Accordingly, some sodium sulphate was added to the partially refined nickel-copper ore in the furnace. When the molten material was poured into pots, allowed to cool, and dumped out on the floor, it was found that something unusual had happened. There was a distinct difference between the top and bottom parts of the cones of metal, and these could be broken clean apart with a sledge hammer. The bottom was a bright sulphide which proved to be mostly nickel sulphide. The top was mostly copper sulphide. And that was the beginning of the Orford Process of nickel-copper separation — one of the standard processes in use today.

Loading nickel matte (partially refined ore) in 1890 for shipment to refineries in the United States and Great Britain.



Threat of European Control

Meanwhile the very existence of the Canadian Nickel industry was threatened from another direction. Mines had been opened up at great expense. A smelter was built at Copper Cliff near Sudbury in 1887. A large new market seemed to be opening up for nickel. But now, with success almost within its grasp, Ritchie's company found itself almost at the end of its financial resources.

The other companies which had carried on mining and smelting operations in the Sudbury district had all folded up. The Canadian Copper Company alone remained.

Now, too, the makers of armament were looking for new sources of nickel for the world's navies. Krupps of Germany, whom Ritchie had tried to interest in nickel years before, and the Rothschilds of France, were both trying to get control of the Canadian Nickel deposits. It was a big temptation now to sell out at a profit.

Ritchie put the matter squarely up to his associates. They felt the same way about it as he did. They weren't going to sell out to outside interests if they could help it. Sir John A. Macdonald and Sir Charles Tupper also used their influence to keep control of the nickel interests on this side of the ocean.

Finally, by pledging their personal fortunes, Ritchie and his business partners were able to borrow about $250,000 from the banks to put the Company on its feet.

Further Growth

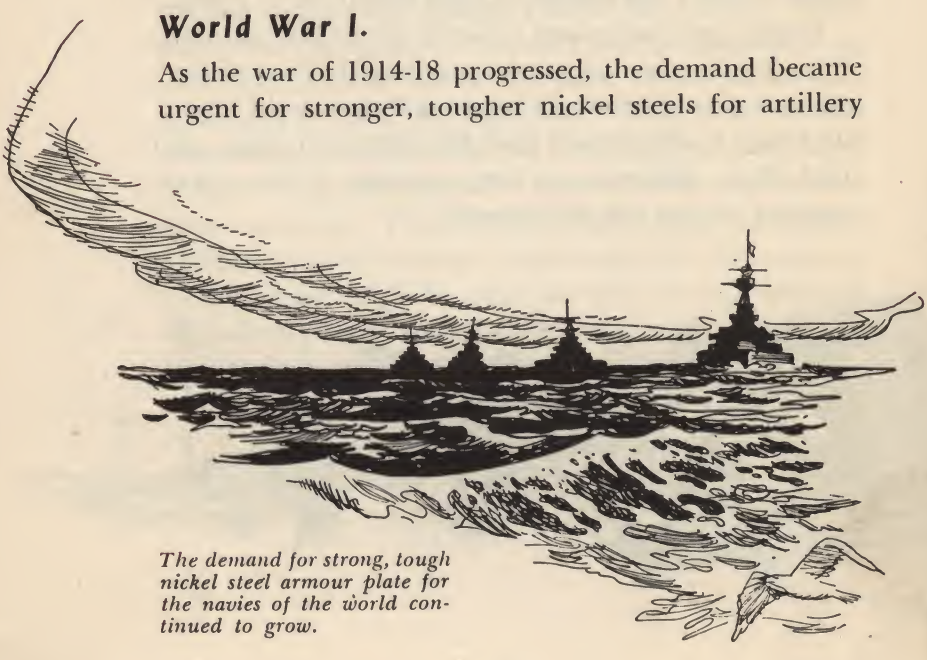
From now on production from the Canadian mines increased steadily. In 1887 the whole world had produced only about two thousand tons of nickel, most of which came from New Caledonia. By 1902 Canadian production alone was more than five thousand tons.

It was at this time that the Canadian Copper Company at Copper Cliff and the Orford Copper Company in New Jersey, which had become dependent on one another, united as The International Nickel Company.

Operations were steadily expanded as the demand for nickel . . . largely for armaments . . . continued to grow. By 1914 the Company production had reached about 23,750 tons a year, while New Caledonia was producing about a third as much.

World War I.

As the war of 1914-18 progressed, the demand became urgent for stronger, tougher nickel steels for artillery



The demand for strong, tough nickel steel armour plate for the navies of the world continued to grow.

Nickel steel was urgently needed for battleships, artillery and scores of wartime uses.

and battleships and scores of wartime uses. The Canadian nickel mines and plants pushed their production to new peaks and nickel ingots were rushed to the steel mills and munition plants in Canada, England, France, and the United States. Thus did nickel strengthen the sinews of the Allied Nations in the first World War.

In 1916 the building of a great new electrolytic refinery was begun at Port Colborne, Ontario, and with its completion in 1918, facilities for producing nickel from ore to finished product in Canada were available.

Starting All Over Again

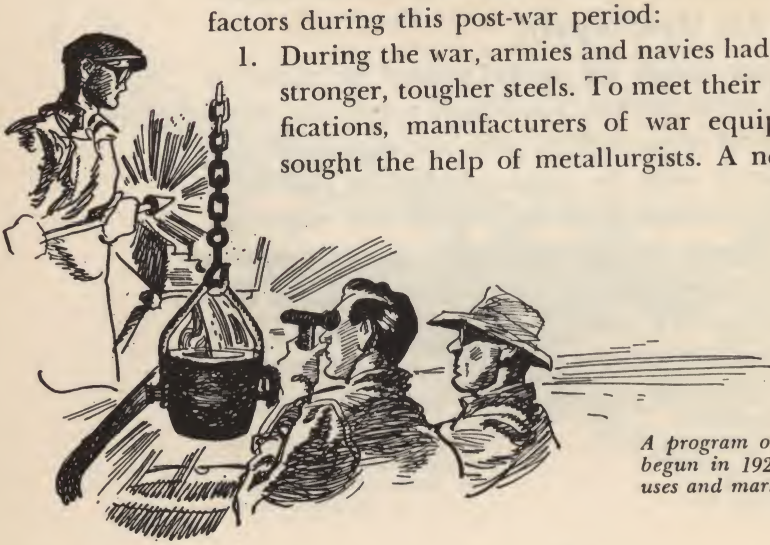
When the war ended, the market created for nickel in armaments and munitions was largely wiped out. With ninety per cent of its markets gone, the nickel industry was confronted with the same problem as had faced Ritchie in 1889. Operations were completely suspended for twelve months during 1921-22 for lack of demand. The nickel industry had to start practically at the bottom and develop new uses and markets for nickel. There were no established paths to follow. Few people had experience with the use of nickel by itself or as an

The Canadian nickel plants were closed for twelve months during 1921-22 for lack of markets.

alloying element. After laboratory experiments had indicated mechanical or chemical advantages through the use of nickel under certain conditions, it was necessary to find fields where these conditions existed, and urge prospective customers to try the new material. In most cases, nickel was replacing other well established materials which could be obtained at lower first cost. Nickel and nickel alloys had to compete with all commercially used metals and with innumerable alloys, as well as painted and coated materials of various kinds. The prospective customer usually had to be convinced of the economic advantage of replacing his present material with a more expensive metal.

As it turned out later, there were three favourable factors during this post-war period:

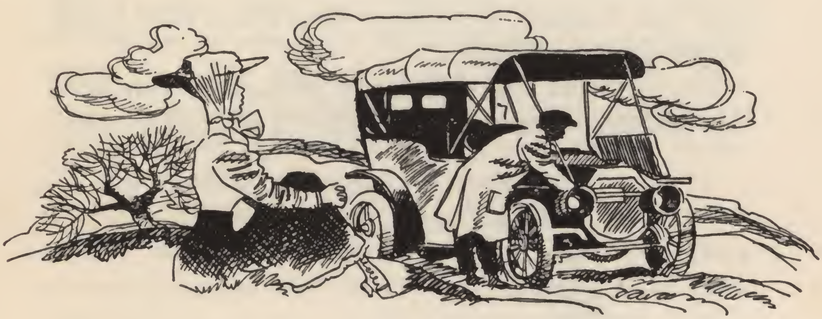
1. During the war, armies and navies had demanded stronger, tougher steels. To meet their rigid specifications, manufacturers of war equipment had sought the help of metallurgists. A new interest



A program of research was begun in 1922 to find new uses and markets for nickel.

developed in alloys. Nickel alloys were among the most important.

2. During the post-war period of increased industrial activity, there was a constant demand for better materials for the new machines, products and appliances which were invented and developed. Nickel and its alloys were among the most important of these new materials.
3. The automobile, subject in its early years to stripped gears and broken axles, gradually developed rugged dependability largely through the use of strong, tough nickel alloy steels. As more cars were sold more nickel was used. The automotive industry became the largest single customer for nickel.



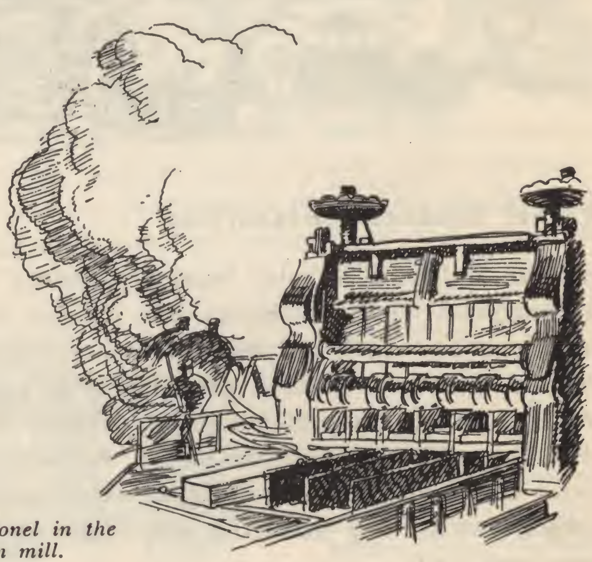
Nickel Research Intensified

In 1922 Robert C. Stanley became president of The International Nickel Company. He realized that the same qualities which had made nickel pre-eminent in the war could also make it pre-eminent in peacetime industry. Under his guidance, a broad policy of active research and development was begun. Research laboratories were built, and metallurgists with practical experience in the key industrial and engineering fields were employed.

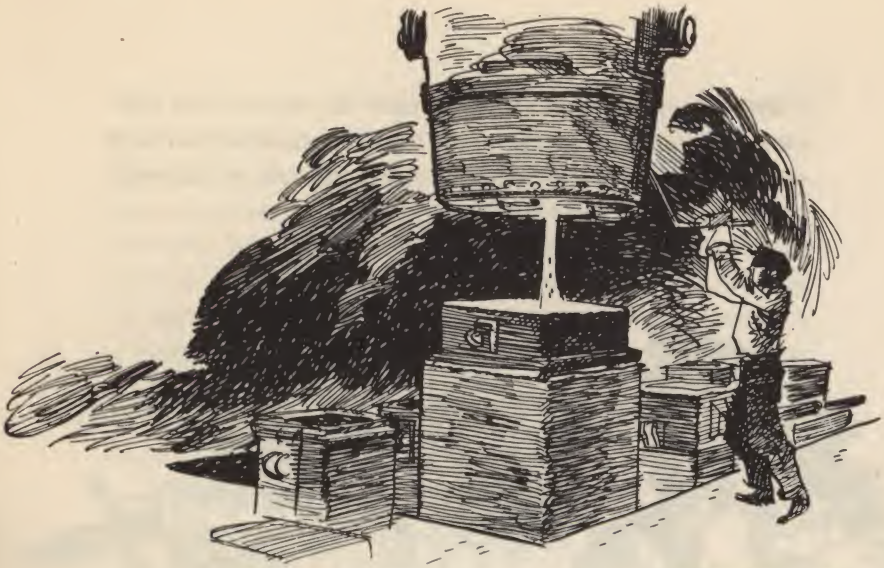
As part of this program it was believed that the markets for nickel would be increased if the Company could extend the uses of nickel in mill products, principally for Monel, an alloy produced direct from the ore in approximately the same nickel-copper ratio as found in the Creighton Mine. This alloy had been sold in small quantities since 1905, but its use was limited by the fact that it was not readily available in the standard mill forms of rod, sheet, strip and wire. Because of the rolling difficulties and the small tonnages, it was found after trial that it was impracticable to make adequate arrangements for rolling Monel on a toll basis.

The answer was the construction of a mill for the production and development of Monel and other high-nickel alloys. In 1921, as part of the development program, a refinery and rolling mill were built at Huntington, West Virginia, to produce these alloys from partly refined smelter products.

The ore from which Monel is produced is converted into an intermediate product which is shipped to Hunt-



Rolling Monel in the Huntington mill.



Pouring Monel ingots.

ington where there is an abundance of sulphur-free natural gas for use in the final refining and the rolling operations. The finished Monel, a silvery-white alloy with important mechanical and chemical properties, has many uses in engineering and in the food, chemical, shipbuilding and many other industries.

At the Huntington mill, modifications of Monel * such as "K" * Monel and "R" * Monel, and other alloys of nickel such as "Z" * Nickel and Inconel * have been developed, each with its special mechanical and chemical characteristics. The availability of a wide range of forms of Monel and other nickel alloys, made possible by the Huntington mill, has not only expanded the market for these alloys, but has encouraged other producers to develop special alloys, many of which contain nickel. An example is stainless steel, which, at first a specialty, is now produced by many of the steel companies in large tonnages.

* Trade Marks.

Steadily the demand for nickel increased. By 1929 more nickel was being used in the peaceful pursuits of industry than during the peak period of wartime production.

In 1928 the Frood mine was opened.

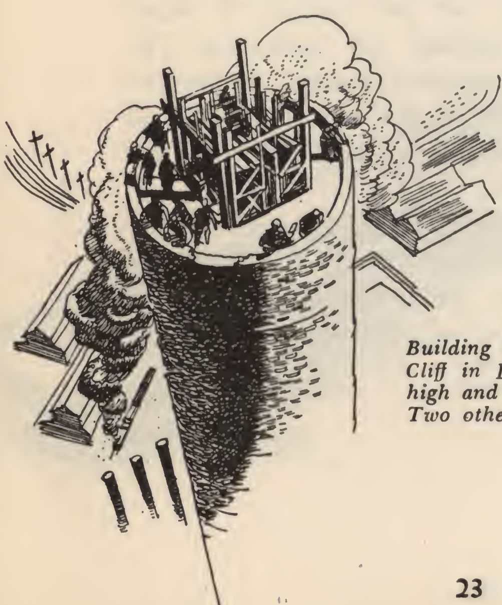
Sudbury Properties Integrated

In the late twenties The International Nickel Company of Canada, Limited, and The Mond Nickel Company, Limited, each started a mining operation in the Sudbury Basin which proved to lead to the same ore body — the Frood — the largest single nickel ore body ever discovered, and the heart of the Canadian nickel industry. If this ore body were developed through two separate operations, it was evident that a large part of the shafts and underground development to extract the ore, as well as the surface facilities to handle it, would have to be duplicated. Only under a single long-term mining plan would it be possible to develop the entire ore body properly so as to ensure the full utilization of all ore.

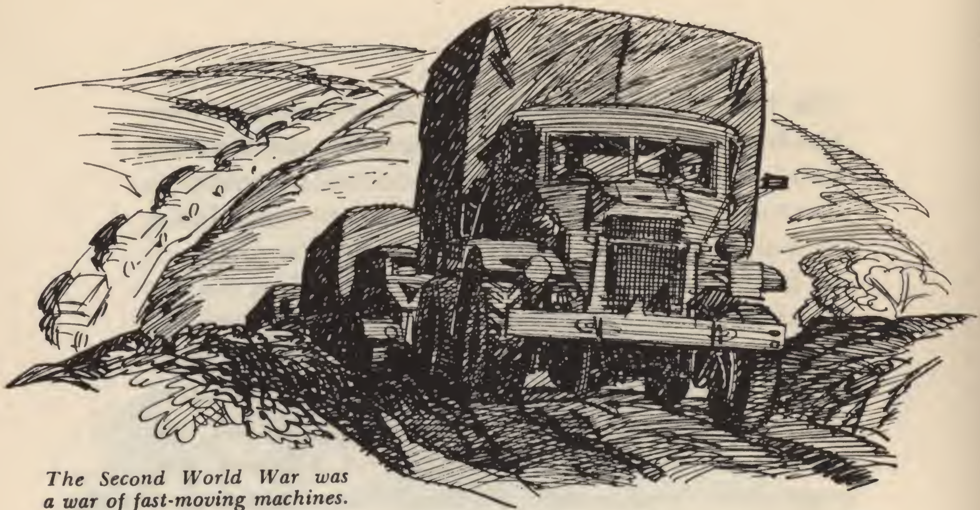
In 1929, The Mond Nickel Company merged with The International Nickel Company of Canada, Limited. This allowed The International Nickel Company to plan the orderly and effective development of the Frood ore body. The Mond refinery at Clydach, Wales, close to the British industrial markets, as well as rolling mills at Birmingham and Glasgow and a precious metals refinery at Acton, England, also became a part of The International Nickel Company. This bettered the position of the Company in respect to European markets, and resulted in an expanded program of research and world-wide development of demand for nickel and nickel alloys.

The Second World War

The Company's policies of constant research and development of new markets which brought about the great expansion of peacetime uses of nickel, and thus made necessary the tremendously expanded production facilities, had also brought the North American nickel industry to a position of preparedness when the second world war broke out. In efficiency, in capacity, and



Building one of the chimneys at Copper Cliff in 1929. This chimney is 510 feet high and 45 feet inside diameter at top. Two other chimneys now flank this one.



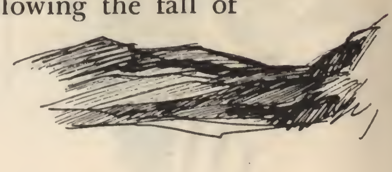
The Second World War was a war of fast-moving machines.

in strategic location of its plants, it was admirably equipped to support the war production effort of the Allied Nations.

This was a mechanized war in which victories were to be won by the armies, navies and air armadas with the strongest, toughest, fastest, most powerful machines.

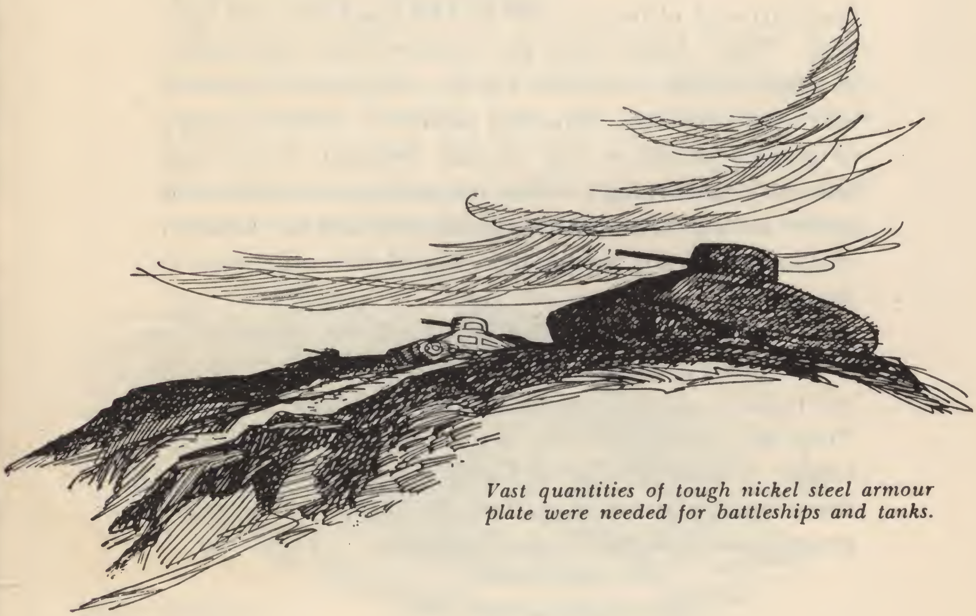
Soon the demand for nickel for war production made it impossible for the Company to supply the peacetime customers it had taken so long to cultivate. By a system of Government priorities, the total output of nickel was made available to essential war industries. The Company co-operated with governmental authorities and nickel users in conserving the nickel supply and in recommending substitutions for nickel in uses for which it was not available.

Because of the loss by the Falconbridge Nickel Company of the use of its refinery in Norway, the Company, as an emergency measure, undertook the refining of the entire Falconbridge output. Following the fall of

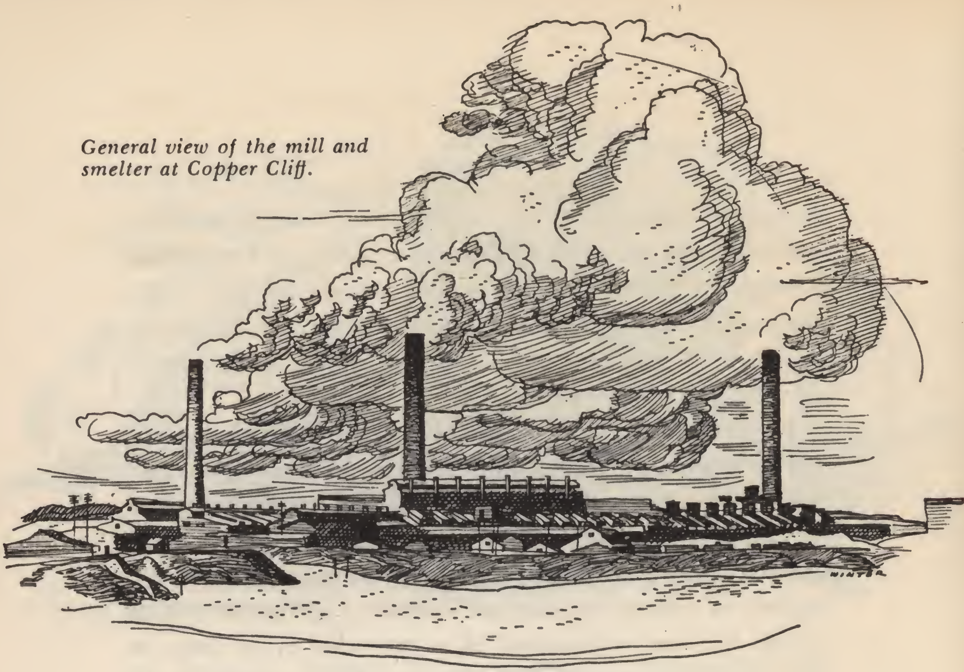


France in 1940, the ores mined and smelted in New Caledonia by Societe Le Nickel were shut off from their refinery in France. To meet this situation, The International Nickel Company installed emergency refining facilities at Huntington, West Virginia, and refined these ores for the United States Government.

To assure adequate supplies for the war requirements of the United Nations, the Allied Governments placed before The International Nickel Company the problem of what could be done further to increase the production of nickel. In response, the Company further enlarged its plants in Canada, under a program which called for the expansion of practically every step in the Canadian production process. This expansion involved the expenditure of $35,000,000 to allow for a yearly nickel production capacity of 50,000,000 pounds more than the 1940 production.



Vast quantities of tough nickel steel armour plate were needed for battleships and tanks.

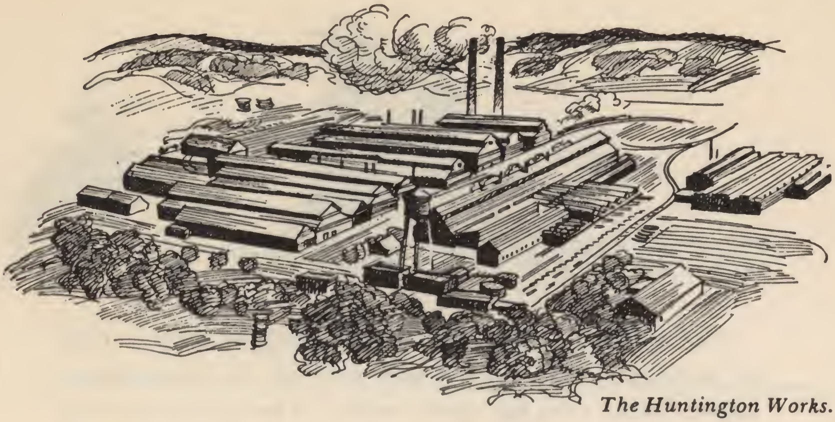


General view of the mill and smelter at Copper Cliff.

International Nickel Today

Today the Company owns 100,000 acres of mineral land near Sudbury, in which the Frood-Stobie and four other underground mines, as well as two open pits, are operated. These mines with the concentrator and smelter at Copper Cliff constitute a single integrated operation laid out to develop, mine and produce a constant supply of nickel geared to the market demand. Long-range planning has brought about the most economical utilization of both low and high-grade ores and an extension of the life of the mines that would not otherwise be possible.

From the smelter at Copper Cliff the bulk of the nickel passes to the large nickel refinery at Port Colborne where pure nickel is produced. All the copper separated from the Company's ores is refined at the Company's copper refinery at Copper Cliff. Some of the power for these operations is furnished by three hydro-electric power plants owned by the Company.



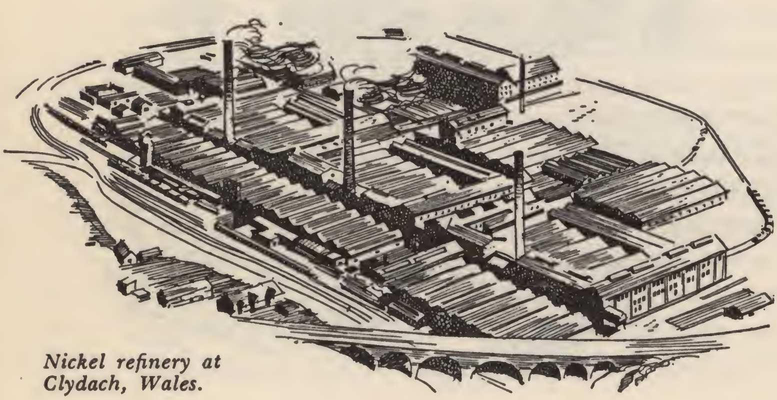
The Huntington Works.

The Company also has a nickel refinery in Clydach, Wales, a Monel refinery at Huntington, West Virginia, and a precious metals refinery at Acton, England.

The Company operates a foundry in Bayonne, New Jersey; rolling mills in Birmingham, England and Huntington, West Virginia; tube and extrusion mills in Huntington and in Glasgow, Scotland; and research laboratories in Canada, England and the United States.

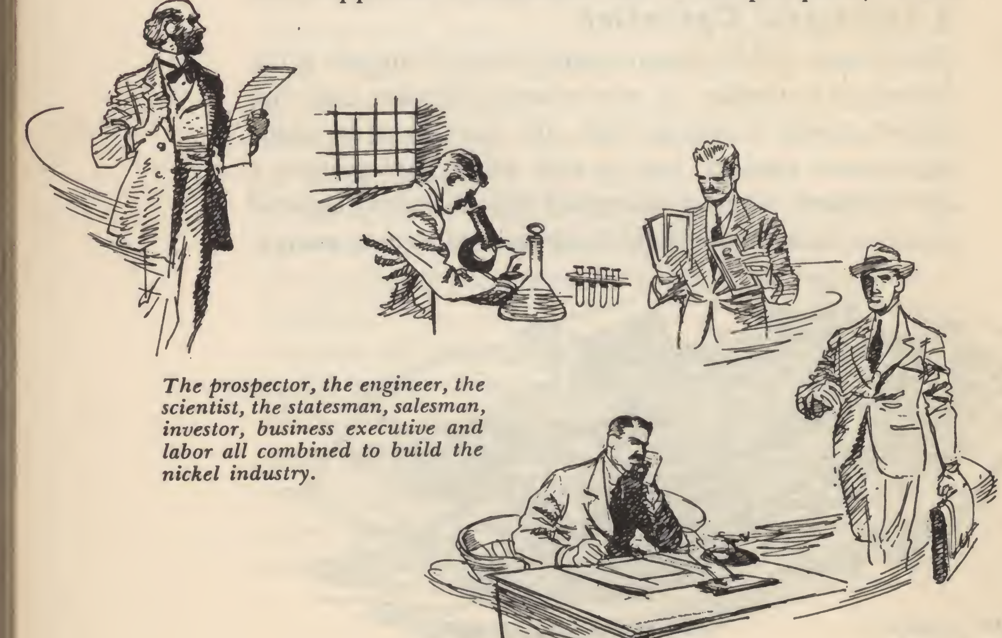
A Successful Operation

The history of The International Nickel Company is the history of a number of men whose judgment time has proved sound. Looking back, the development seems logical and natural; but to look ahead and picture a great industry where nothing had existed before required creative vision, indomitable courage and tireless energy.



Nickel refinery at Clydach, Wales.

And so the nickel industry grew step by step as each of its leaders built firmly and well on the foundations laid by those who had gone before. The prospector and the engineer, the scientist, the statesman, the salesman, the investor and the business executive—each gave his best endeavours. These men contributed their life's work, their skill, their wealth and their knowledge. By ingenuity and skill in processing and constant efforts in developing the usefullness of nickel, they converted an impurity in copper ores into a vital material for modern industry. And they established something permanent and enduring—something which contributes to the welfare and happiness of mankind; and to the prosperity of all.



The prospector, the engineer, the scientist, the statesman, salesman, investor, business executive and labor all combined to build the nickel industry.

PART TWO:

HOW NICKEL IS PRODUCED

Medical and recreational centre for International Nickel employees in Sudbury has tennis courts, billiard tables, bowling alleys, boxing and wrestling facilities. Employees receive medical and hospital care for a small monthly fee.

Sudbury, a thriving city of 40,000 population located in that region of rugged rock and crystal lakes north of Georgian Bay, is the centre of Canada's nickel industry. Four miles to the west, at Copper Cliff, are located great crushing, concentrating and smelting plants. Eight miles to the east, at Coniston, a small smelting plant is in operation. Within a radius of ten miles of Sudbury, The International Nickel Company operates five underground mines and two open pits; a sixth underground mine is located twenty miles from Sudbury on the northwestern rim of the Sudbury Basin. Let us follow

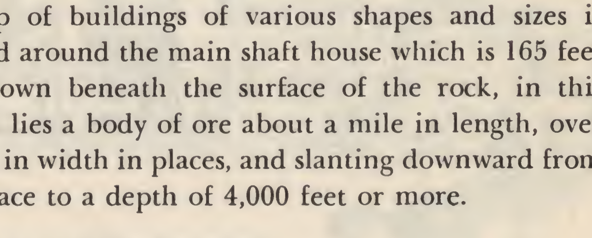
the broad, new highway northward for one mile from Sudbury between low, rocky hills, to the Frood-Stobie Mine.

Mining

A group of buildings of various shapes and sizes is clustered around the main shaft house which is 165 feet high. Down beneath the surface of the rock, in this vicinity, lies a body of ore about a mile in length, over 600 feet in width in places, and slanting downward from the surface to a depth of 4,000 feet or more.

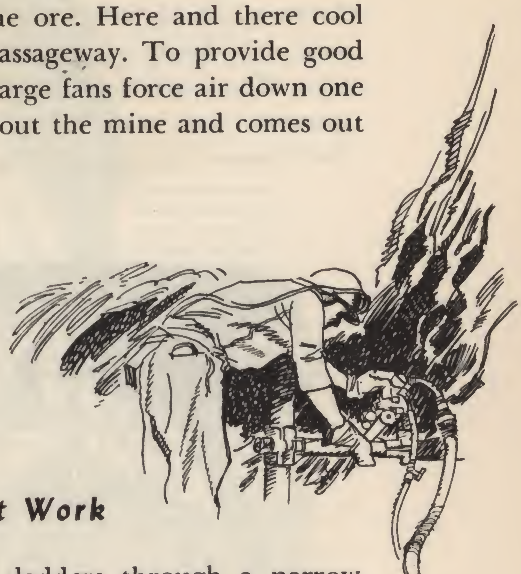
Underground

Equipped with coveralls, helmet and miner's lamp, we enter the cage and drop down into the earth to a depth of 1600, 2000, or even 2800 feet. The cage door opens and we step out into an electrically lighted room cut in the solid rock. Narrow-gauge tracks lead away into long tunnels. We walk along one of these roomy passage-



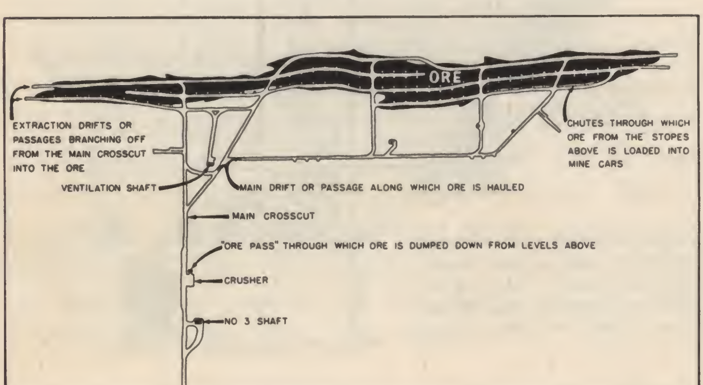
Men coming out of the cage on the 2,800 level on their way to work in the mine.

ways for half a mile or more, then turn into a side tunnel which runs into the ore. Here and there cool breezes sweep along the passageway. To provide good ventilation underground, large fans force air down one shaft. It circulates throughout the mine and comes out through another shaft.



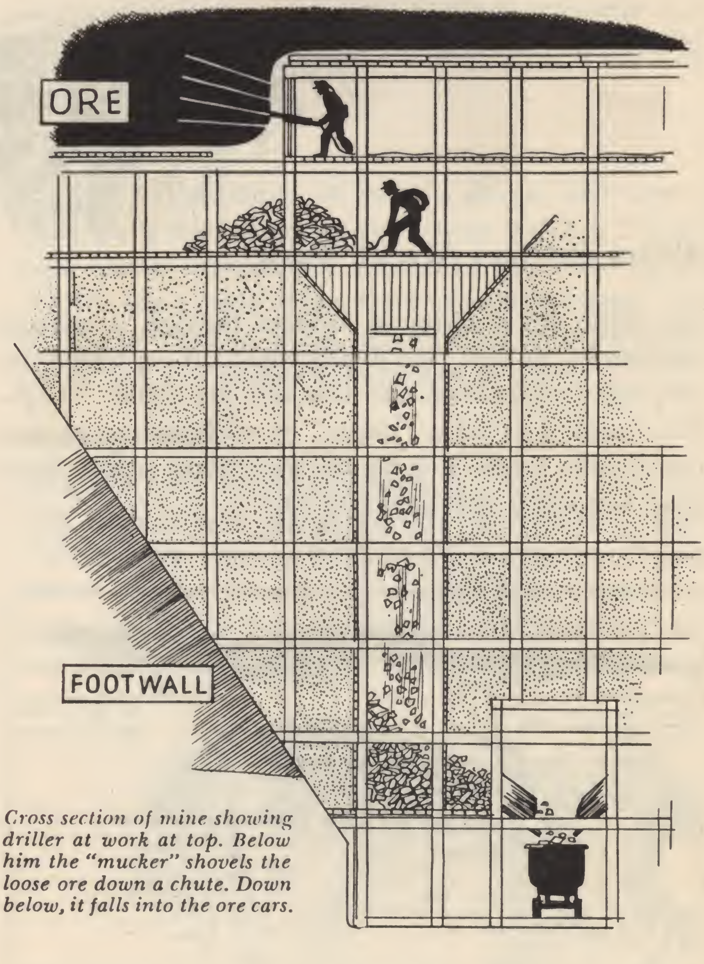
Where Drillers Are at Work

We climb up a series of ladders through a narrow opening in the rock, and finally enter a room where the only light comes from our own and the miners' lamps. This room is called a "stope." Its walls have a glittering metallic lustre. It is floored with heavy plank. Stout posts support a timbered ceiling.

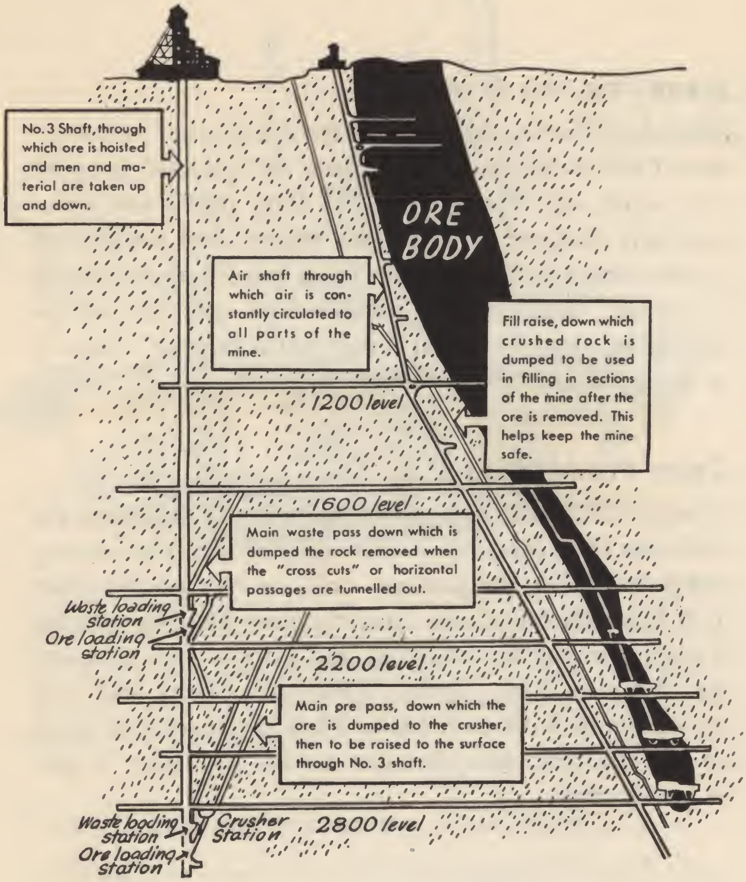


Plan of a level in a nickel mine.

Over at one wall of the stope, the drillers are at work. To the rattle of compressed air machines, the long drills pierce the breast of the ore, to a depth of six or seven feet. When the wall is riddled with holes, powder is inserted, fuses made ready, and at the end of the shift the fuses are lighted and the miners depart.



Cross section of mine showing driller at work at top. Below him the "mucker" shovels the loose ore down a chute. Down below, it falls into the ore cars.



Section through No. 3 shaft, Frood mine.

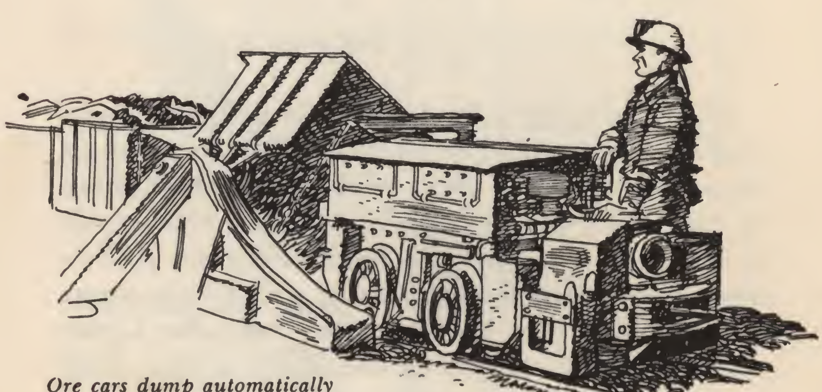
When the charge is fired the whole wall, to a depth of seven feet or more, crumbles and falls to the stope below. The next shift comes on the scene. They timber up the section which has just been blasted, and proceed to drill another six or seven feet into the ore. And so they advance, step by step, cutting a slice right across the ore body. They then mine the next slice higher up. Below them they fill in the mined sections with crushed rock to keep the mine safe.

Handling the Ore

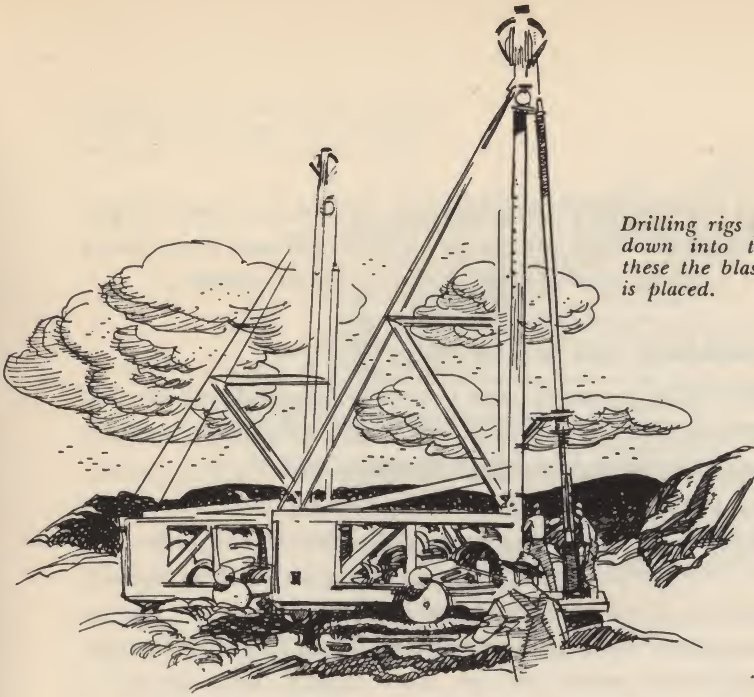
Behind and below the drillers, men known as "muckers" shovel the loose ore down a chute. It is loaded into ore cars which are hauled away in long trains and automatically dumped to a crusher where steel jaws break up the larger lumps of ore. Then steel buckets known as "skips" operated by cables whisk the ore to the surface in 11-ton loads at 3,000 feet a minute, where it is dumped at the shaft house into bins.

Open Pit Mining

The great Frood-Stobie ore body, being mined from the 3800-foot level upwards, is also being mined from the top downwards. On the surface, drilling rigs pound nine-inch holes 60 feet down into the ore. Blasting powder is placed in the set of holes, and once a day, at noon, the charge is fired. About 12,000 tons of ore and rock are shattered with each blast. Then great shovels scoop up the ore into thirty-five-ton trucks, and away it goes to the crusher.



Ore cars dump automatically as the electric locomotive pulls them over a tipple.



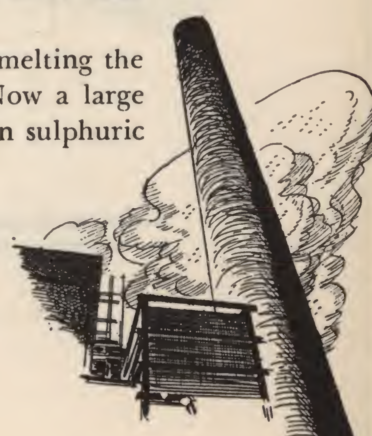
Drilling rigs pound holes down into the ore. In these the blasting powder is placed.

This open pit is being cut down into the rock in steps or "benches," and the pit becomes narrower as it becomes deeper, so surface mining can only be carried on until the two sides of the cone-shaped pit come together at the bottom.

Crushing, Concentrating, Smelting

As we approach Copper Cliff, three huge chimneys loom up from a vast group of buildings down below. Two of these chimneys are respectively 40 and 45 feet inside diameter at the top, and rise to a height of more than 500 feet.

Formerly the sulphur fumes released in smelting the ore killed the vegetation in this district. Now a large part of the sulphur is recovered and used in sulphuric

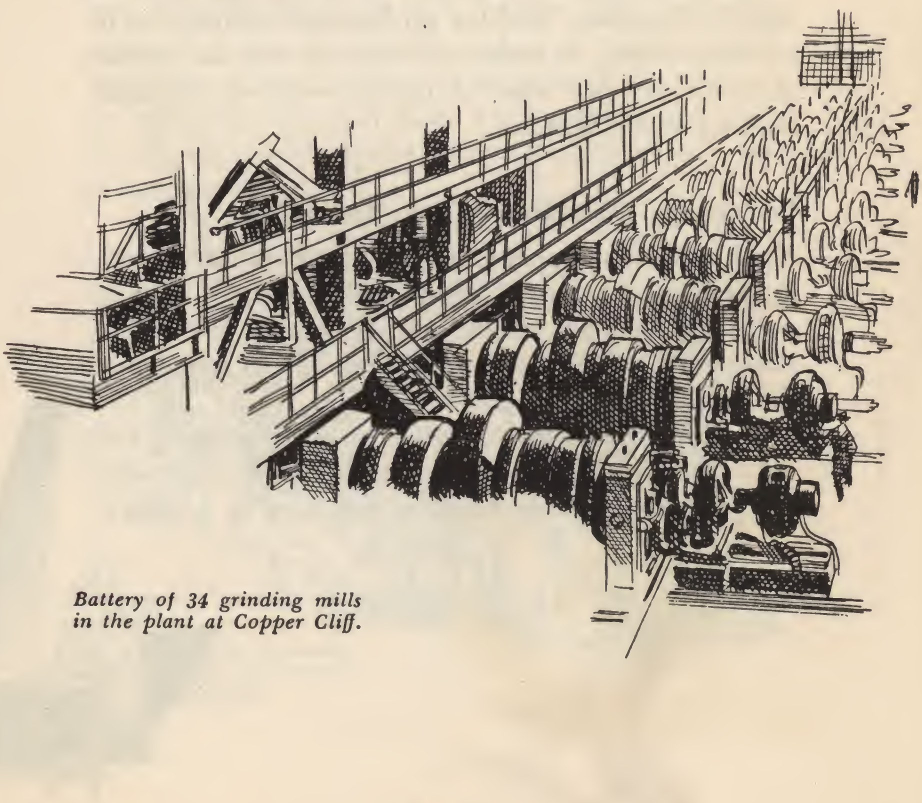


acid manufacture. The balance, carried to a great height through these chimneys, is so well diffused that lawns and gardens now thrive in the Sudbury district.

Crushing and Grinding

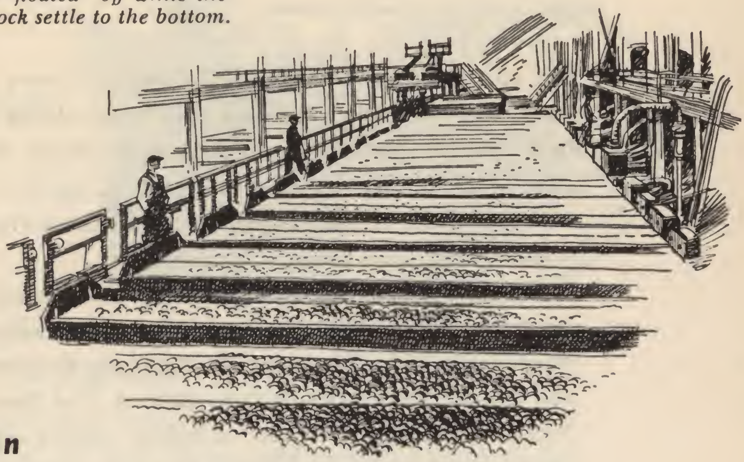
The ore, as it comes from the mine, is composed of rock and a number of minerals which contain nickel, copper, iron, sulphur and a small quantity of precious metals. The purpose of crushing and grinding is to break the particles of rock away from the mineral sulphides.

In a building several times as large as a modern hockey stadium, giant cone crushers and rolls crush the ore to one-quarter inch diameter or less. Then in long batteries of grinding mills the ore, now mixed with water, is ground as fine as fine sand.



Battery of 34 grinding mills in the plant at Copper Cliff.

Flotation tanks where the mineral particles are "floated" off while the particles of rock settle to the bottom.

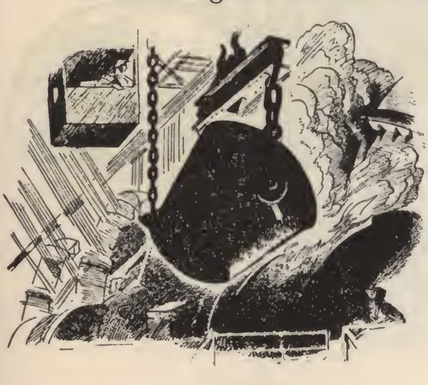


Flotation

In long rows of tanks, by a specialized process, the mineral particles are "floated" off, while the rock particles settle to the bottom. Then in other tanks the copper sulphides are "floated" off and the nickel sulphides settle to the bottom. From this separation process two products emerge, one of which contains most of the nickel and some copper; the other containing most of the copper and some nickel. Then in settling tanks and filters most of the water is removed and the remainder, looking like black mud, goes to the smelter.

Smelting

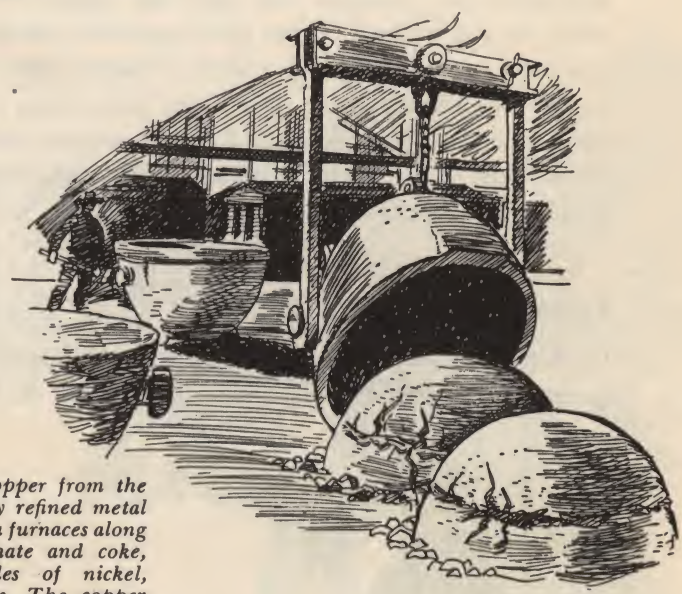
In the huge smelting plant, the nickel concentrate is roasted in great hearth furnaces to get rid of most of



Converters in operation at Copper Cliff.

the sulphur. It is melted in reverberatory furnaces, and most of the impurities skimmed off as slag. Still in a molten state it is conveyed in huge ladles and poured into the converters. Sand or quartz is added and air is blown into the mixture. This burns off more sulphur and gets rid of the iron.

What is left, now known as Bessemer matte, is separated by the Orford process into nickel sulphide and copper sulphide. The copper "tops" are further purified and transferred in the molten state to The International Nickel Company's copper refinery nearby—the largest copper refinery in the British Empire, where its O.R.C. Brand of copper is produced. The nickel "bottoms" are broken up and shipped to the nickel refinery at Port Colborne.



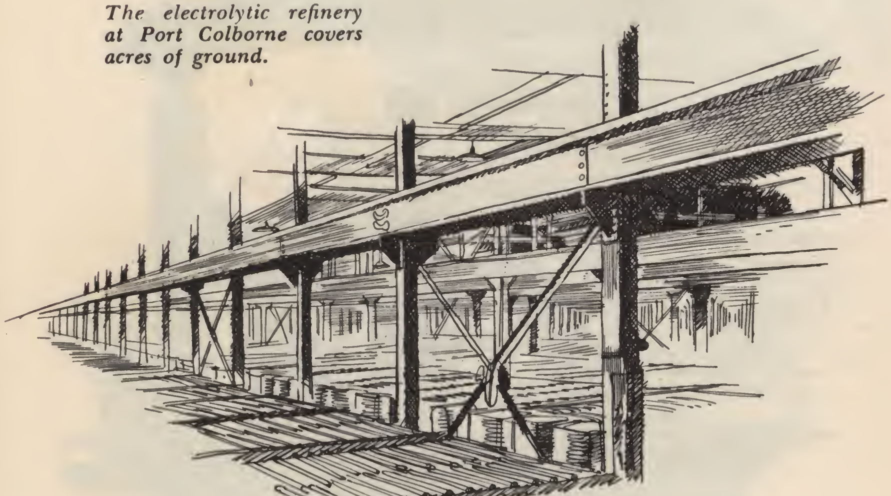
To separate the copper from the nickel, the partially refined metal is smelted in cupola furnaces along with sodium sulphate and coke, producing sulphides of nickel, copper and sodium. The copper sulphide dissolves in the sodium sulphide. When the melt is tapped into pots the heavier nickel sulphide settles to the bottom. When cool, the top can be neatly broken apart from the bottom.

Machine which casts the molten nickel into anodes.

Refining in Canada

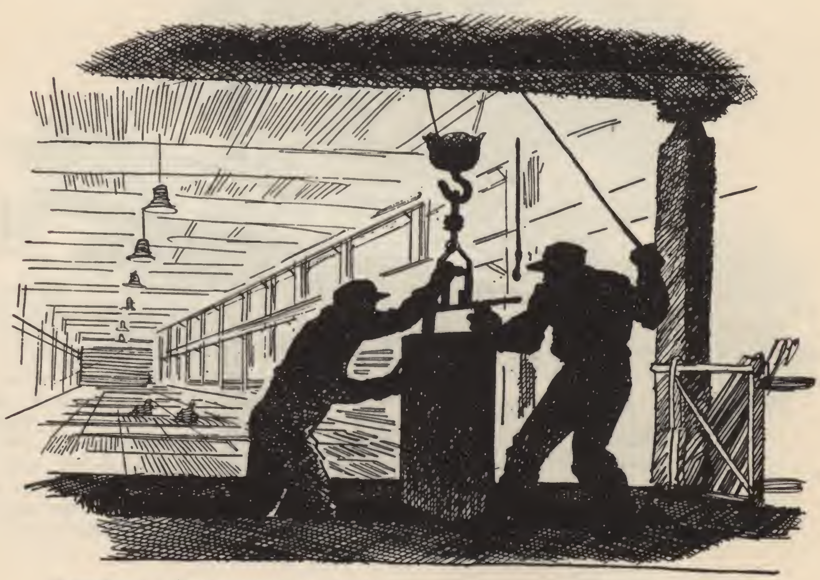
At Port Colborne, Ontario, where the waters of Lake Erie enter the Welland Canal, and close to the plentiful supply of electric power from Niagara Falls, is located The International Nickel Company's great nickel refinery.

Here the nickel "bottoms" from the Copper Cliff smelter are crushed and ground, washed with hot water to remove the sodium sulphide, roasted to remove more sulphur, melted in oil-fired furnaces and poured into moulds. The resulting 425-pound slabs of metal go to the electrolytic refinery as anodes.



The electrolytic refinery at Port Colborne covers acres of ground.

This vast refinery covers twelve acres of ground and is filled with row upon row of concrete tanks. The anodes, consisting of impure nickel and containing a small percentage of platinum metals, are lowered into a nickel sulphate solution in the tanks. The impure nickel anodes are slowly eaten away by the electrolytic process and the nickel is deposited as cathodes. These cathodes which are 99.9% pure nickel, including a fraction of a per cent of cobalt, are removed from the tanks and cut up into the sizes required by the various users of electrolytic nickel. The residue from the tanks contains the platinum and other precious metals. This is concentrated to remove a large part of the impurities, and the concentrate goes to the company's platinum metals refinery in Acton, a suburb of London, England. From it are obtained gold, silver, platinum, palladium, rhodium, ruthenium and iridium. This refinery supplies about half the world's requirements of platinum metals which are used for a host of industrial purposes as well as for fine jewelry.



Removing nickel cathodes (99.9% pure nickel) from electrolytic tanks.

PART THREE:

WHAT NICKEL IS USED FOR

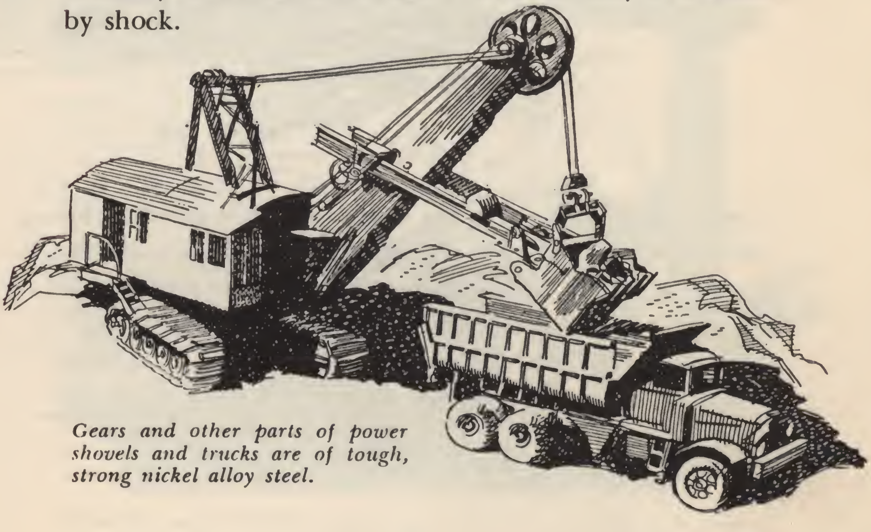
Until about fifty years ago there was little demand for nickel except for nickel plating, for nickel coins, and for nickel silver to make articles for domestic use and as a base for silver-plated ware. Since that time, and especially since 1921, hundreds of additional uses have been discovered for this metal, largely through scientific research.

Strong, Tough Nickel Steels

Nickel itself is strong and tough and resists wear; it also imparts these same qualities to other metals with which it is mixed or "alloyed." When added to steel, for instance, it produces an alloy that is stronger, tougher and more resistant to wear.

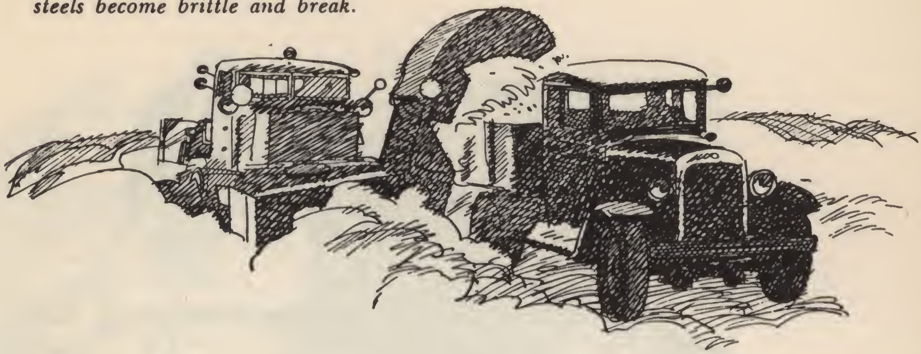
Because of their greater strength, steels containing from ½% to 5% nickel are very extensively used for the gears, steering parts, crankshafts and other vital parts of automobiles. The great strength and toughness of nickel steels are even more essential in many parts of trucks, buses, tractors, steam shovels and freight cars because these must stand up under repeated heavy shocks and strains. Nickel steels are used in all types of machinery in mills, factories and shops; in ship propulsion machinery; in the machinery used for drilling, producing and refining petroleum; in the engines and landing gears of aeroplanes.

Other nickel steels are used in sub-zero temperatures —in cold climates, and in oil refineries and liquid air machinery at temperatures as low as —300°F., where ordinary steels tend to become brittle and may be broken by shock.



Gears and other parts of power shovels and trucks are of tough, strong nickel alloy steel.

Nickel steels stand up in sub-zero temperatures where ordinary steels become brittle and break.



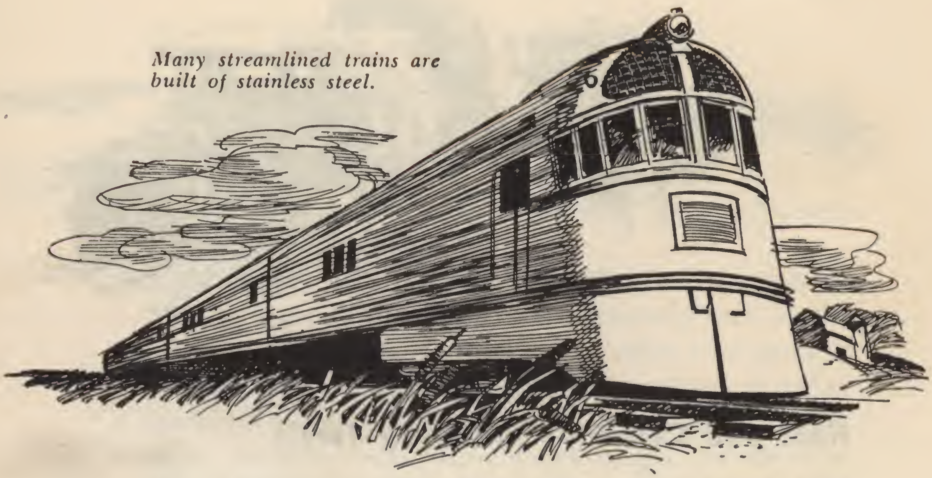
Heat and Corrosion Resisting Steels

Nickel does not rust, and stoutly resists corrosion by salt water, by many acids, caustics and other chemicals. It also stands up under heat. So nickel, when alloyed with steel along with chromium or other alloying elements, helps to make those metals resistant to heat and corrosion too.

Stainless steel, for instance, containing 8% nickel and 18% chromium, is used in hotel and restaurant kitchens and in food processing plants because it resists the corrosion of the food juices and does not contaminate foods. Many modern streamlined trains are completely built with a stainless steel framework and encased in stainless steel sheets so thin, yet so strong, that weight and operating costs are substantially reduced. Ordinary steel sheets would soon rust through—the stainless steel does not even need the protection of paint.

Heat resisting steels containing nickel are used in industrial furnaces, gas turbines and other applications where they give strength and long service at high temperatures.

Many streamlined trains are built of stainless steel.

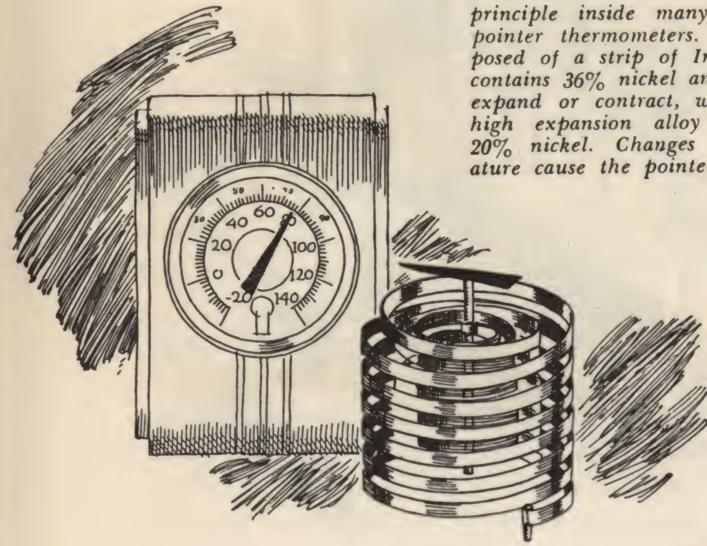


Special Nickel Alloys

Many unusual alloys are required in the intricate instruments and equipment of various kinds being used today, and many special alloys containing from 2% to 90% nickel have been developed for these special services, and for equipment which must stand up at high temperatures and under corrosive conditions.

Through the use of nickel, alloys have been developed that are magnetic, others that are non-magnetic. Non-magnetic alloys are widely used in aeroplane instruments, and magnetic alloys in the radio and telephone industries. A special nickel-iron alloy whose magnetic properties change with temperature is used in practically all automobile speedometers to avoid error from changes in temperature.

Special nickel alloys have also been developed which show practically no expansion or contraction in chang-

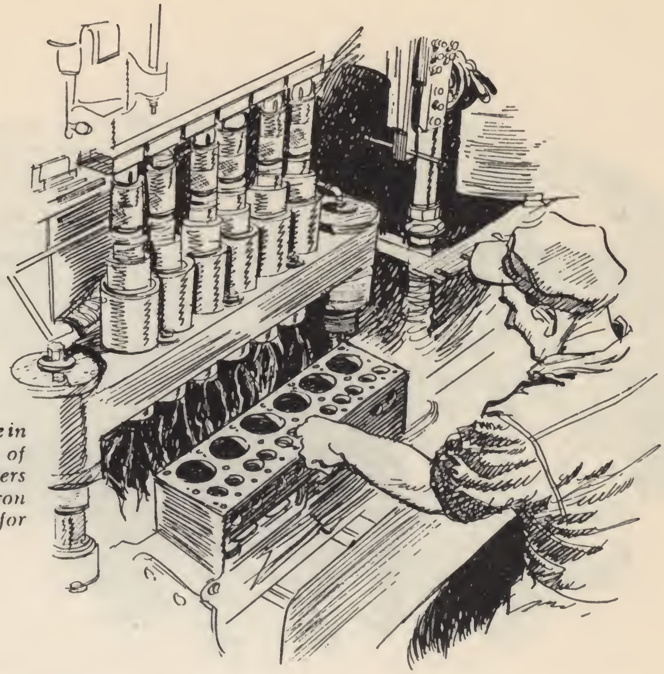


This double coil is the motivating principle inside many dial and pointer thermometers. It is composed of a strip of Invar, which contains 36% nickel and does not expand or contract, welded to a high expansion alloy containing 20% nickel. Changes in temperature cause the pointer to rotate.

ing temperatures—others that expand and contract a great deal in heat and cold. These are widely used in thermostats.

Nickel Cast Iron

In the years following the first World War when the nickel industry was depressed due to lack of markets, nickel research scientists began a thorough study of cast iron. Taking advantage of all experimental work previously carried out by other research scientists, they proved conclusively that cast iron could be improved by adding small percentages of nickel. Nickel makes the metal finer and more uniform in texture. It also increases its strength, wear resistance, toughness and resistance to corrosion.

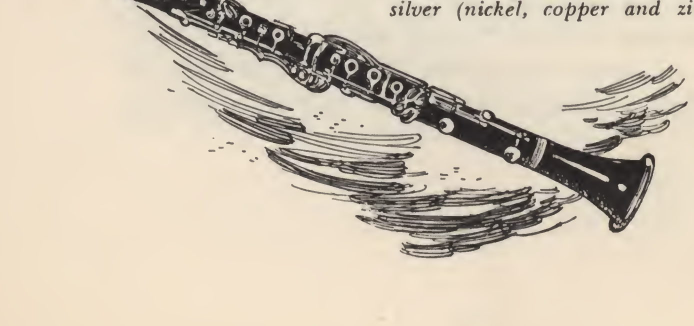


Precision machine in final operation of polishing cylinders in nickel cast iron cylinder block for automobile.

Since that time nickel alloy iron has been adopted for scores of new uses. It is widely used in the machine tool industry for the beds of lathes and heavy machine tools. The engine blocks and cylinder heads of gasoline and diesel engines are generally made of nickel alloy iron.

Nickel Alloyed With Many Metals

In this modern world we find nickel being alloyed with a great number of metals where special characteristics are required. It is alloyed with copper, brass and bronze



Clarinet keys are made of nickel silver (nickel, copper and zinc).

to give greater resistance to corrosion and wear, or to give a white color; with aluminum to provide a metal that is strong but light in weight; with molybdenum, cobalt, titanium and gold.

Nickel in Everyday Life

Actually nickel is with you and does things for you from the time you get up in the morning until you go to sleep at night.

Let us start with the clock beside your bed. Nickel plating gives it its cheerful, rust-proof shininess. If it is an electric clock, magnetic nickel alloys make possible its compact size and low current consumption.

If the house is cold, you turn on the heat. The valve is of tough nickel bronze. If the furnace is an oil burner —a good oil burner—the fire pot is made of a heat-resistant nickel-chromium-iron alloy.

Now you're in the bathroom. The clean, hot water is often heated in a rust-proof Monel tank. As you brush your teeth, remember—in plants where tooth pastes are

made, their purity is guarded by Monel and pure nickel equipment. The soap you use was processed in kettles of nickel-clad steel, Monel or pure nickel.

Nickel steel and nickel cast iron have been used in the machinery that made your shoes. As for your clothing, dyeing machines of nickel-chromium alloys, since they are not acted upon by the dye solutions, have made possible the delicate shades so popular these days.

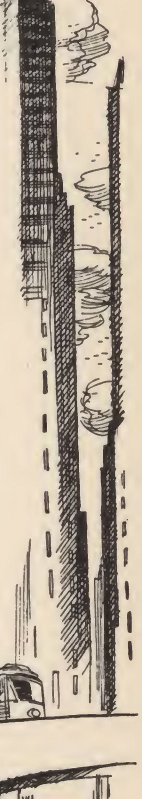
At Breakfast

And now for breakfast! In a silver-plated nickel silver percolator you make your morning coffee. Nickel-chromium wire has come into general use for electrical heating elements because it stands heat so well. It makes your toast, and cooks the food on your electric range. In the packing plant where your bacon was cured the equipment which came in contact with the meat was stainless steel—sanitary and easy to keep clean. Even the purity of the salt on your table depends on nickel. In the salt refinery, wet salt and brine rapidly corrode most metals, but Monel suffers no ill effects whatever. And as for sugar, filters of Monel mesh now give much longer service in sugar refineries than the canvas filters formerly used.

In Cars, Trucks, Buses

Now you're on your way to the plant or office. Whether you ride in a street car, bus or automobile you can rest assured that a good deal of nickel was used in its manufacture. By using alloys of nickel with iron, steel, aluminum and copper, engineers are able to produce parts that are smaller and lighter but tougher and longer lasting—parts that stand up under higher temperatures, higher pressures and faster speeds. Nickel is also essential to prevent the rusting of the metal trim of your car. Its bumpers and hardware having a durable and protective coating of nickel under the bright chromium finish.

Even the gasoline in your tank was "cracked" in a still utilizing corrosion-resistant nickel-chromium-iron, stainless steel, and nickel-copper alloys.



For greater strength, freight cars are fabricated from nickel alloy steel.

On the Railroad

If you have to take a trip on the train, you will be interested to know that sturdier engines and freight and passenger cars are being built today, and at the same time their weight is being reduced, by stronger alloys containing nickel. In modern locomotives, steam pressures and temperatures have climbed to points that would have been impossible a few years ago. So the locomotive of today pulls a much greater load in proportion to its weight, because of the tougher, stronger, longer-lasting nickel alloys used in its construction.

Nickel Has Thousands of Uses

As you walk along the street you see a foundation being dug for a new building. Nickel steel parts give strength and shock resistance to that burrowing power shovel. The life of the tractors down there has been lengthened by the use of nickel alloy steel in parts that must stand abuse. Cranes are lighter and stronger than they used to be, because of nickel steel.

Far up overhead a plane is defying height and distances. Nickel alloys, because of their strength and resistance to heat, have contributed greatly to the efficiency, safety, durability and light weight of the modern aero engine.

No matter what restaurant you pick at lunch time, you'll find nickel a big factor in its operation. Back in the kitchen Monel and stainless steel are used for sinks, steam tables and other surfaces which come in contact with food. These nickel-bearing metals are good-looking, sanitary and easy to keep clean. The flatware you use, your forks and spoons, are made from stainless steel or silver plate on a nickel silver base.

In the Home

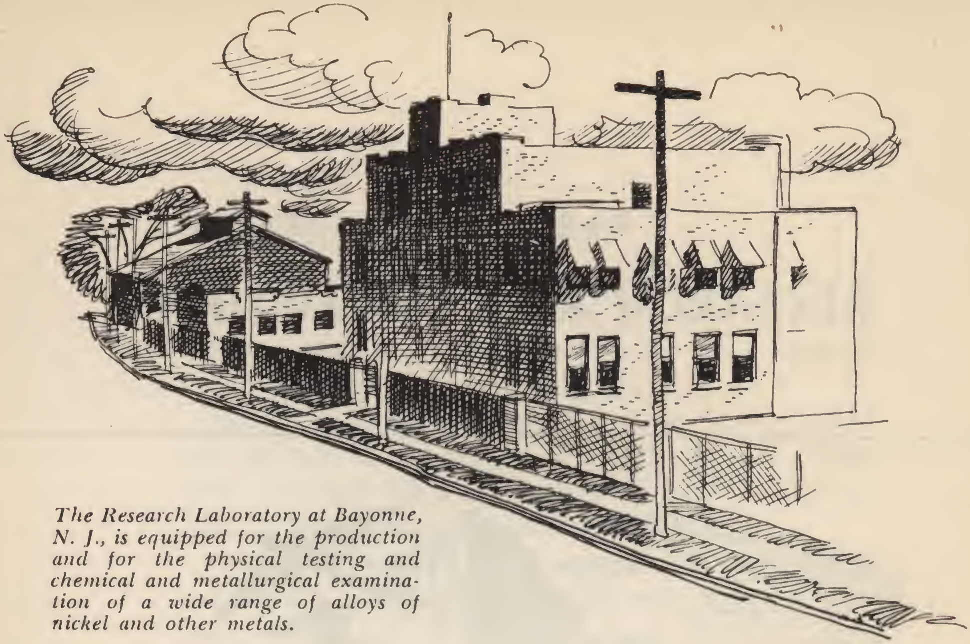
Back home at the end of your working day you sit down and turn on the radio. In the tubes for today's radios as well as for the television sets now being developed, pure nickel is employed.

After dinner someone suggests a movie. If it's a technicolor picture, nickel has played a big part in its production, for nickel alloys are used in the special machinery used in developing and transferring the film.

When you return home you open the door with a nickel silver key. As you settle down to sleep at night and pull the bed clothes up around your shoulders, don't forget that the sheets were bleached and laundered in machines made of Monel. Because of its corrosion resistance, it keeps them clean and spotless.

PART FOUR:
RESEARCH AND THE FUTURE

Endowed by nature with a gamut of useful properties, nickel has the ability to improve many metals or, in many instances, to form alloys with entirely new properties. Scientific research and development work have uncovered many of nickel's secrets and, step by step, this knowledge has been put to work for the benefit of mankind.



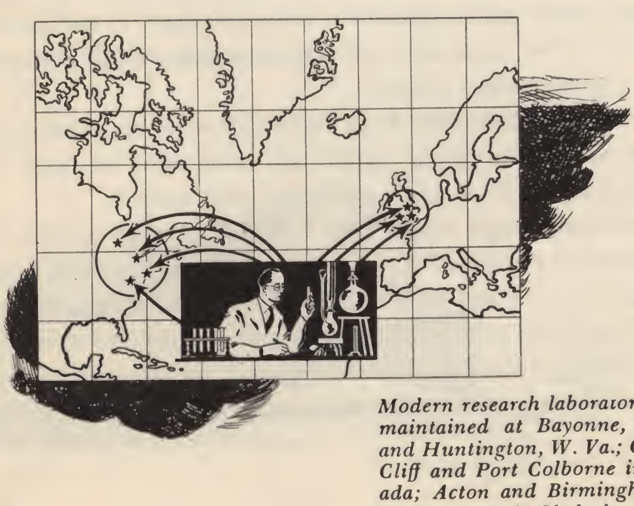
The Research Laboratory at Bayonne, N. J., is equipped for the production and for the physical testing and chemical and metallurgical examination of a wide range of alloys of nickel and other metals.

In the field of material requirements the phases of research and development are interdependent. Whereas engineering developments have often created new material requirements, new materials have, in turn, often led to greater technical advances. This is an ever-continuing process and the goal is being advanced as new fields are entered.

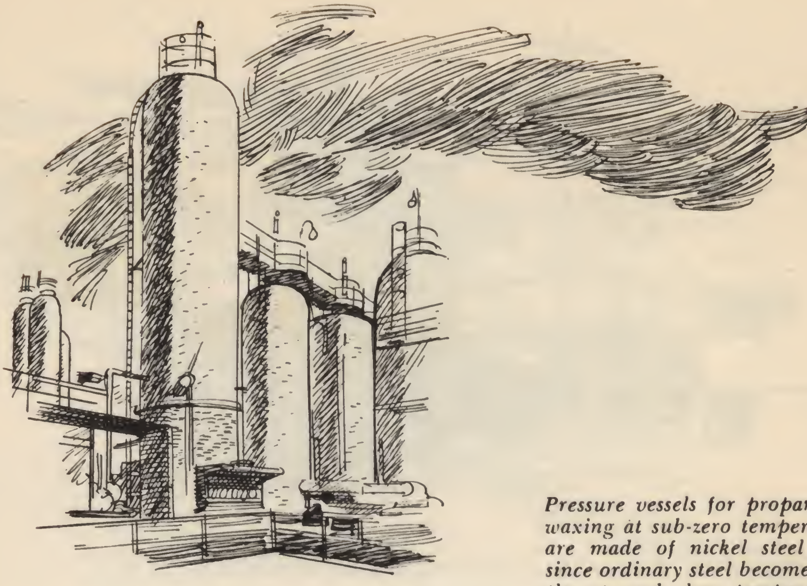
Previous Research Creates Demand

The research of other industries, as well as the extensive work done in the nickel industry itself, has greatly expanded the knowledge of nickel. This research has led to an understanding not only of the properties and uses of nickel itself, but in particular the part this metal plays when alloyed with other metals, including iron, chromium, copper and aluminum. This knowledge has led to the acceptance of nickel by engineers, metallurgists and managers of industry, whose material requirements are governed by technical and engineering facts, as a metal having diversified and extremely useful properties. Indicative of the versatility of this metal are the results of a recent survey showing that today over 3000 alloys in current use contain from a fraction to something less than 100% of nickel.

In World War II, nickel was a resourceful ally in the construction of war materials and equipment. The knowledge gained previously in the extensive development of commercial applications was of great value in the production of the necessities of modern warfare. New uses and applications were also developed, many of which were converted to peacetime use after V-J Day. The other applications of nickel and nickel products discovered during the emergency of war will no doubt have far-reaching results in years to come in further enlarging the sphere of nickel for commercial use.



Modern research laboratories are maintained at Bayonne, N. J., and Huntington, W. Va.; Copper Cliff and Port Colborne in Canada; Acton and Birmingham in England; and Clydach, Wales.



Pressure vessels for propane de-waxing at sub-zero temperatures are made of nickel steel plate since ordinary steel becomes brittle at such low temperatures.

The Years To Come

Industry is in an era of unprecedented engineering thought and research. In the years to come, as scientific research spurs industry on to new accomplishments, the search will be intensified for metals having properties capable of increased or special performance.

Tougher, stronger alloys will be sought to stand up under extraordinary conditions of service and nickel alloy steels will supply new demands, just as today they serve in the crankshafts of diesel engines or in the gears of a giant steam shovel.

To resist abrasion hard materials will be needed like the nickel cast irons which are used now to resist the grinding wear of coal, coke, ore and sand.

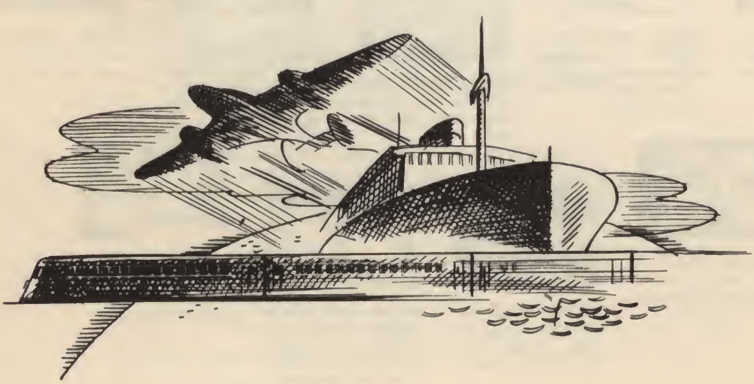
Strong, tough alloys that will not corrode will be required to protect the purity of foods and chemicals with which they come in contact. Monel and stainless steels will serve in new applications just as they are now used for equipment in plants engaged in processing food and making chemicals and pharmaceuticals.

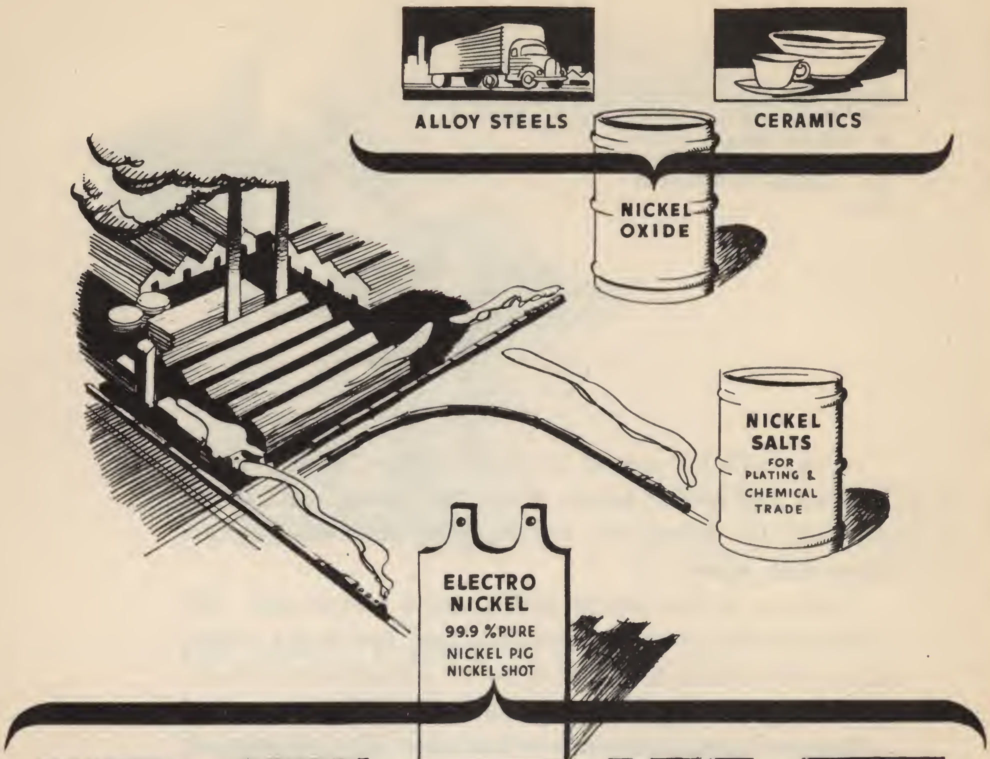
To give strength at the high operating temperatures of jet engines, designers have chosen high-nickel alloys for various component parts.

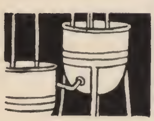
Alloys will be needed to resist intense heat, even as Inconel and other nickel alloys are being used today to stand up under the terrific heat generated in jet-propelled planes.

Industry in the future will demand metals that will withstand extremely low temperature, just as the nickel alloys are serving today at sub-zero temperatures in oil refineries and liquid-air equipment.

Research ever leads to new horizons. The students of today, as the scientists and engineers of tomorrow, will explore realms of knowledge undreamed of at the present time. New facts will be learned about nickel. That tough, but friendly metal, will yield additional secrets, to serve you more and more as "Your Unseen Friend" in safeguarding your health, your home and your comfort in the years that lie ahead.





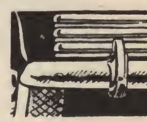


COMMERCIALLY PURE NICKEL for food, pharmaceuticals and chemical plant equipment.

NICKEL ALLOY CASTINGS for corrosion resistant, high strength and pressure castings.

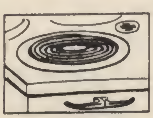
ALUMINUM NICKEL ALLOYS for strength at high temperatures with minimum effect on thermal conductivity.

NICKEL SILVER for architectural use, as a base for silver plated wear, for keys and novelties.

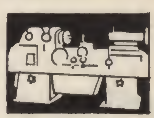


NICKEL ANODES for use in nickel plating for corrosion resistance, durability and appearance.

COINAGE. Coinage of pure nickel or nickel alloys for durability and appearance.



NICKEL - CHROMIUM ALLOYS for strength, high resistance to corrosion and heat, and for electric heating.



NICKEL - IRON CASTINGS for strength and resistance to wear and heat.

ELECTRICAL AND MAGNETIC ALLOYS for motors, television, telephone, radio, controls, and other instruments or equipment.

NICKEL BRONZE for gears, valves, pumps, shafts and bearings.

STAINLESS STEEL for trains, cooking utensils, chemical equipment and many other uses.

COPPER - NICKEL ALLOYS for condenser tubes, electrical equipment and other uses.

MONEL AND OTHER NICKEL-COPPER ALLOYS for high strength, toughness and resistance to rust and corrosion.

NICKEL STEELS for locomotive and automotive parts, machine tools and heavy machinery.

NICKEL
AND ITS IMPORTANT ALLOYS

1. NICKEL
   a. commercially pure wrought nickel (99+% nickel)
   b. coinage (99.4% nickel)
   c. anodes (90 to 99% nickel)
   d. plating (99.9% nickel)
2. NICKEL and IRON
   a. wrought alloy steels (½ to 9% nickel)
   b. cast alloy steels (½ to 9% nickel)
   c. alloy cast irons (1 to 6% and 14 to 36% nickel)
   d. magnetic alloys (20 to 90% nickel)
   e. non-magnetic alloys (8 to 27% nickel)
   f. clad steels (5 to 40% nickel)
   g. thermal expansion alloys (22 to 50% nickel)
3. NICKEL and COPPER
   a. low-nickel alloys (2 to 13% nickel)
   b. cupro-nickels (10 to 30% nickel)
   c. coinage alloy (25% nickel)
   d. electrical resistance alloy (45% nickel)
   e. higher nickel alloys, Monel*, etc. (over 50% nickel)
4. NICKEL and CHROMIUM
   a. electrical resistance alloys (80% nickel)
5. NICKEL and ALUMINUM
   a. cylinder head and piston alloys (2% nickel)
   b. low expansion alloys (1 to 2½% nickel)
   c. bearing alloy (1% nickel)
6. NICKEL, COPPER and ZINC
   a. Nickel silvers (5 to 30% nickel)
7. NICKEL, COPPER and TIN
   a. nickel brasses and bronzes (1 to 15% nickel)
8. NICKEL, CHROMIUM and IRON
   a. stainless steels (2 to 26% nickel)
   b. heat-resisting alloys (12 to 85% nickel)
   c. electrical resistance alloys (35 to 60% nickel)
   d. Inconel* (80% nickel)
9. OTHER ALLOYS
   a. age-hardenable alloys (½ to 98% nickel)
   b. nickel-manganese alloys (94 to 98% nickel)
   c. nickel-molybdenum alloys (55 to 62% nickel)
   d. nickel-silicon alloys (85% nickel)

There are at present over 3,000 active alloys containing nickel in varying proportions — an indication of the importance and versatility of nickel as an alloying element.

Litho in U.S.A.